Water Power

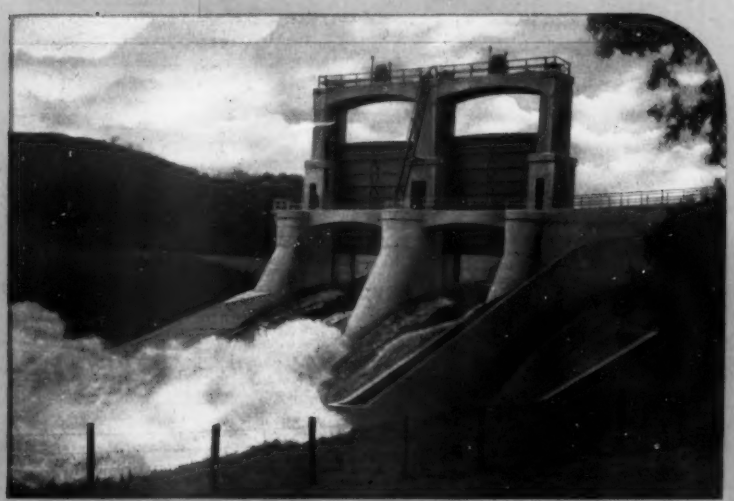
INTERNATIONAL DEVELOPMENT OF HYDRO-ELECTRIC POWER

PRICE 2/6 MARCH 1958

TEXAS TECHNOLOGICAL COLLEGE
MAR 13 1958

Control Equipment

at the Dam ★



in the Pipelines ★

★ at the Power House

Glenfield

Glenfield

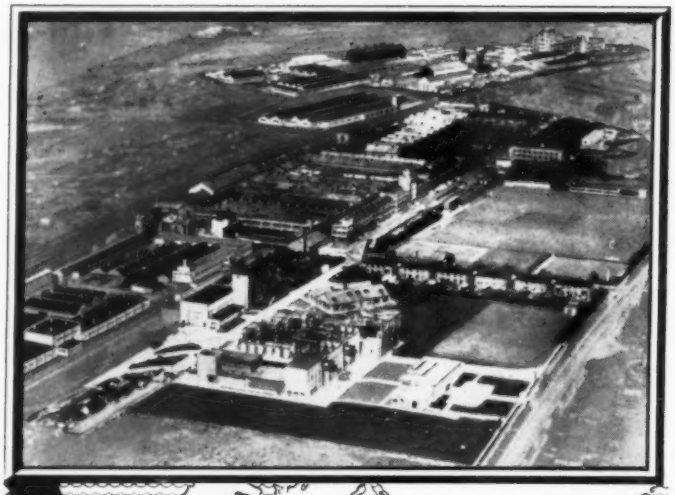
KILMARNOCK · SCOTLAND

HEBBURN–

THE SOURCE

OF ELECTRICAL

SWITCHGEAR



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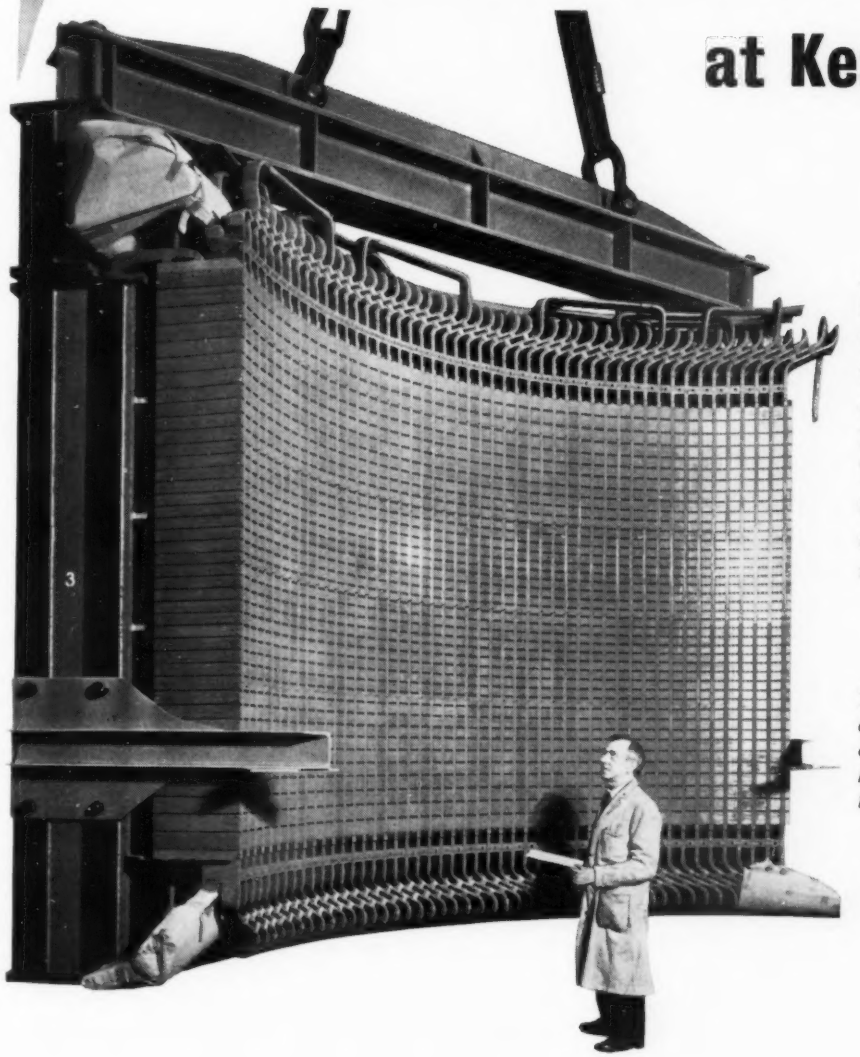
MORE POWER

at Kemano



A repeat order for an alternator for the Kitimat project of the Aluminum Company of Canada has recently been completed. This machine is rated at 114,000 kVA with an overload rating of 132,000 kVA.

The photograph shows a section of the stator of the second machine ready for packing in the works.

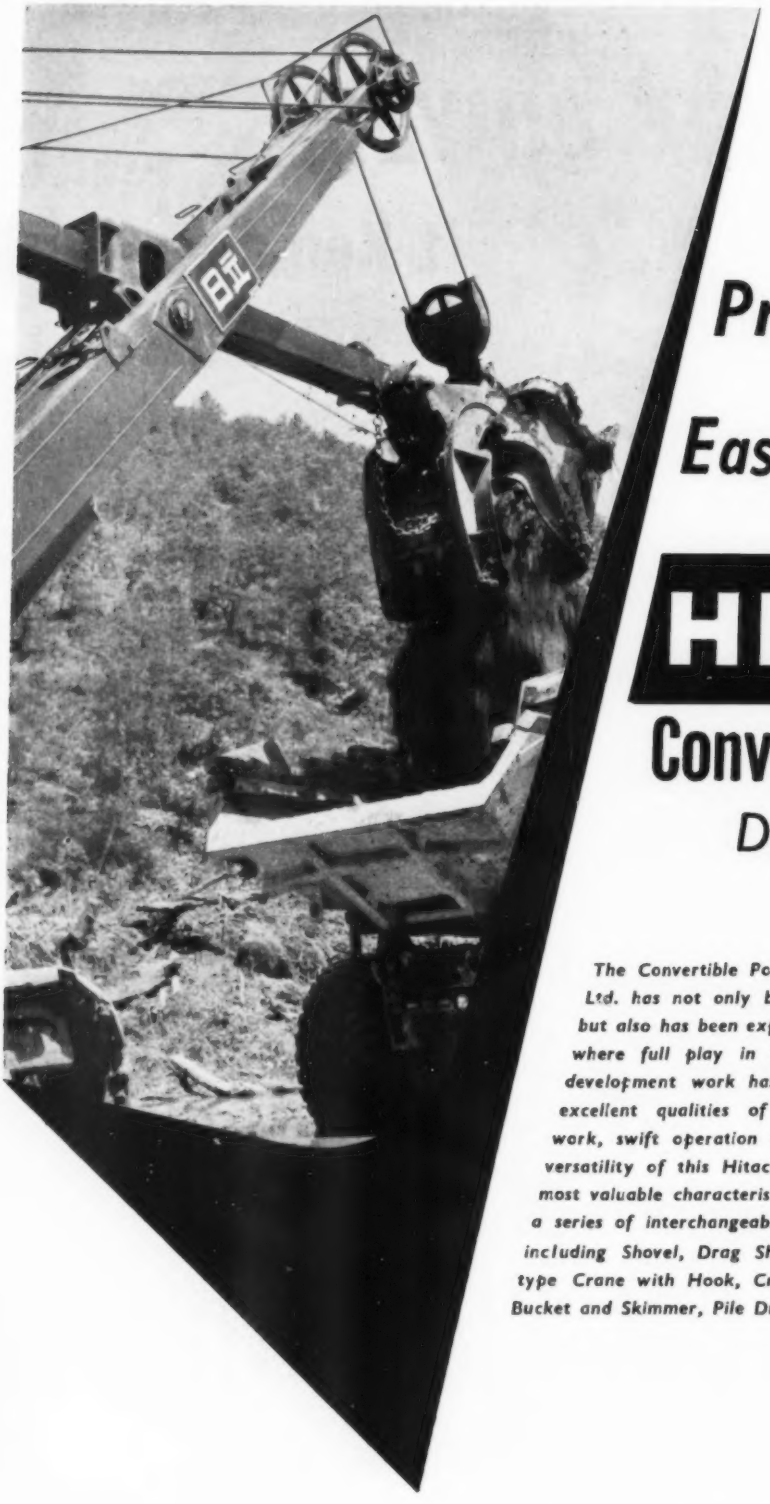
'ENGLISH ELECTRIC'

hydro-electric equipment

THE ENGLISH ELECTRIC COMPANY LIMITED, MARCONI HOUSE, STRAND, LONDON, W.C.2

Hydro-electric Department, Netherton, Bootle, 10

HE.20C8 WORKS: STAFFORD · PRESTON · RUGBY · BRADFORD · LIVERPOOL · ACCRINGTON



Precision built

Easy to handle

HITACHI

Convertible Shovel

Does Big Jobs Fast

The Convertible Power Shovel featured by Hitachi, Ltd. has not only been in extensive use in Japan but also has been exported to many foreign markets where full play in dam construction and other development work has been given to confirm its excellent qualities of solid construction, precise work, swift operation and ease in handling. The versatility of this Hitachi Convertible Shovel is a most valuable characteristic as it can be used with a series of interchangeable front-end attachments, including Shovel, Drag Shovel, Dragline, Crawler type Crane with Hook, Crawler type Crane with Bucket and Skimmer, Pile Driver, etc.

Cable Address: "HITACHY" TOKYO

Hitachi, Ltd.

Tokyo Japan

the largest Pelton turbine in Great Britain

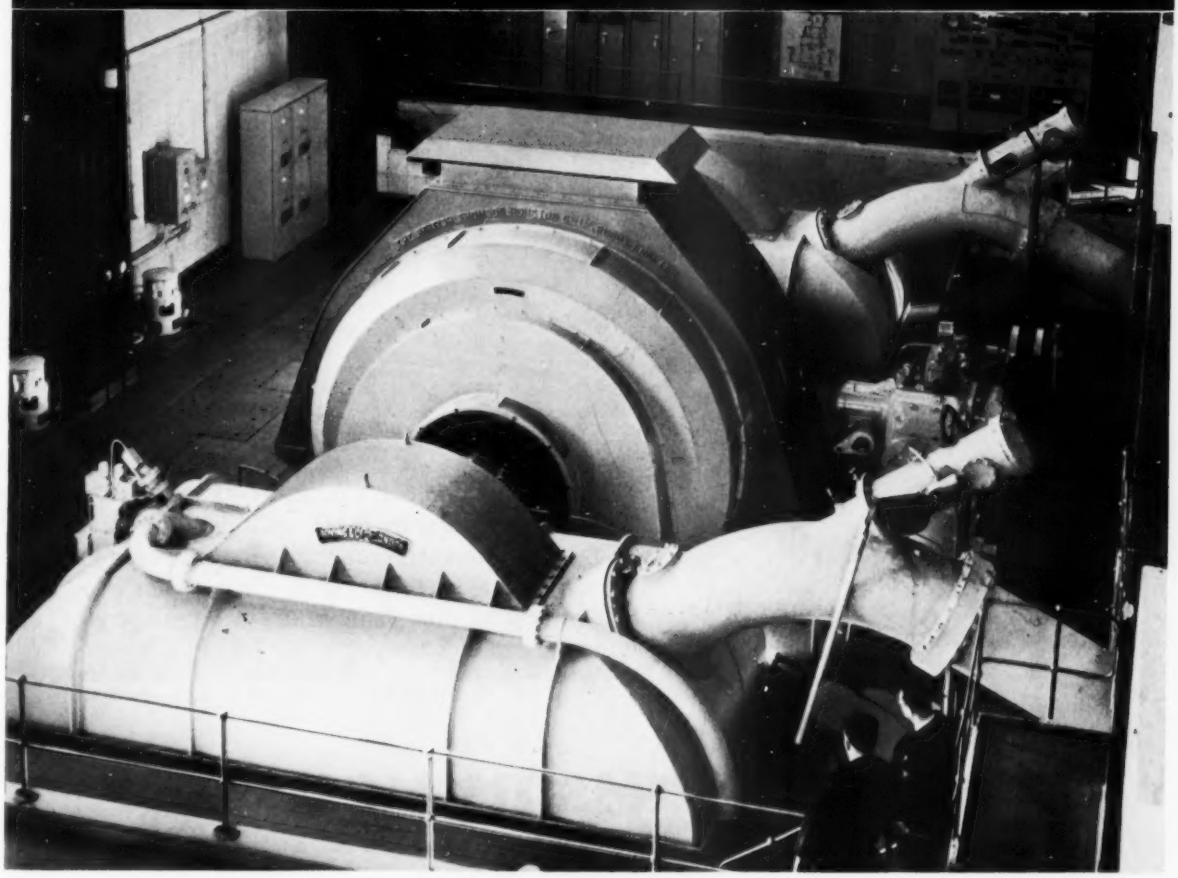
Boving have supplied the 42,000 HP Horizontal Double Overhung 4-jet Pelton Turbine, the largest in Great Britain, for the Finlarig Power Station of the North of Scotland Hydro-Electric Board.

The operating head is 1,250 ft.—the highest in Scotland. The 30,000 kW alternator and other electrical equipment were supplied by The British Thomson-Houston Co. Ltd.

Boving & COMPANY LIMITED

WATER POWER ENGINEERS

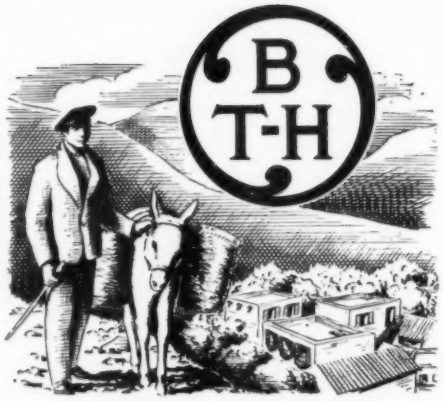
56 KINGSWAY LONDON WC2

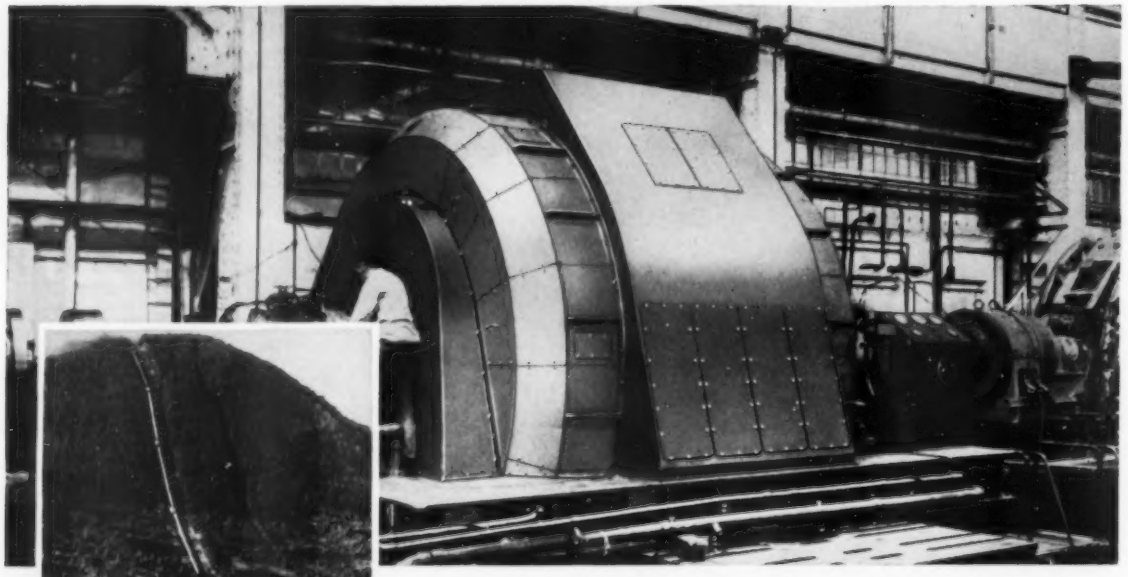


HYDRO-ELECTRIC EQUIPMENT

Power for Spain by

Many of the rivers of Spain and France rise in the High Pyrenees. Their waters are harnessed to supply electric power for railways, for industry and for the domestic supply of the surrounding countryside. Here, at Artias, where the River Garonne leaves Spain for its long flow through France, Sociedad Productora de Fuerzas Motrices, S.A. have built a new power station. It is 3,700 ft. above sea level, and in it BTH equipment is once again used to help harness the power of natural resources.





One of the two BTH generators on test at Rugby Works.

Two 42,500-kVA, 600-r.p.m., 11-kV generators have been supplied by BTH, each driven by two single-jet Pelton turbines supplied by Ets Neyrpic, Grenoble, one wheel being overhung from each end of the generator shaft. These turbines operate under a head of 2,600 ft.

General view of the power station and the penstock.

BRITISH THOMSON-HOUSTON

THE BRITISH THOMSON-HOUSTON COMPANY LIMITED · RUGBY · ENGLAND

Member of the AEI group of companies

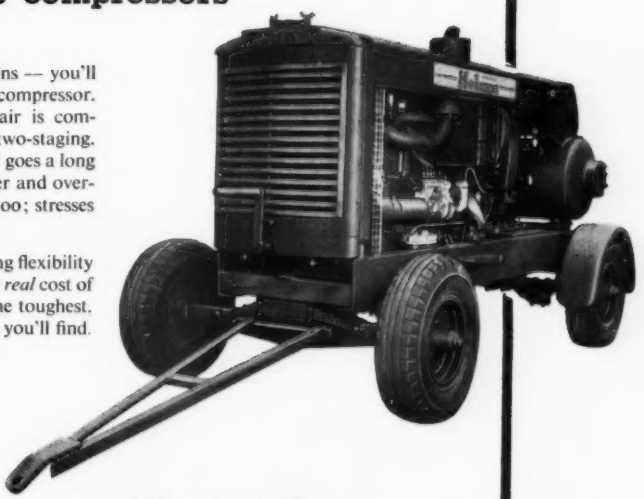
A4971

High output from low power — from sea level to 5000 feet — Holman portable 2-stage compressors

On the seashore or five thousand feet up in the mountains — you'll still get the same high output from a Holman portable compressor. And at low cost, because the maximum volume of air is compressed for a given power. That's one advantage of two-staging. There are others. Temperatures are lower, so a little oil goes a long way — carbon deposits are negligible, valves last longer and overhaul charges are considerably smaller. Friction is cut, too; stresses are reduced and so are the chances of breakdowns.

A Holman portable compressor gives you great operating flexibility and cuts running cost. And it's running cost that is the *real* cost of pneumatic equipment. Get a Holman and you've got the toughest, most efficient and reliable *money-saving* air compressor you'll find.

Hire-purchase terms can be arranged.



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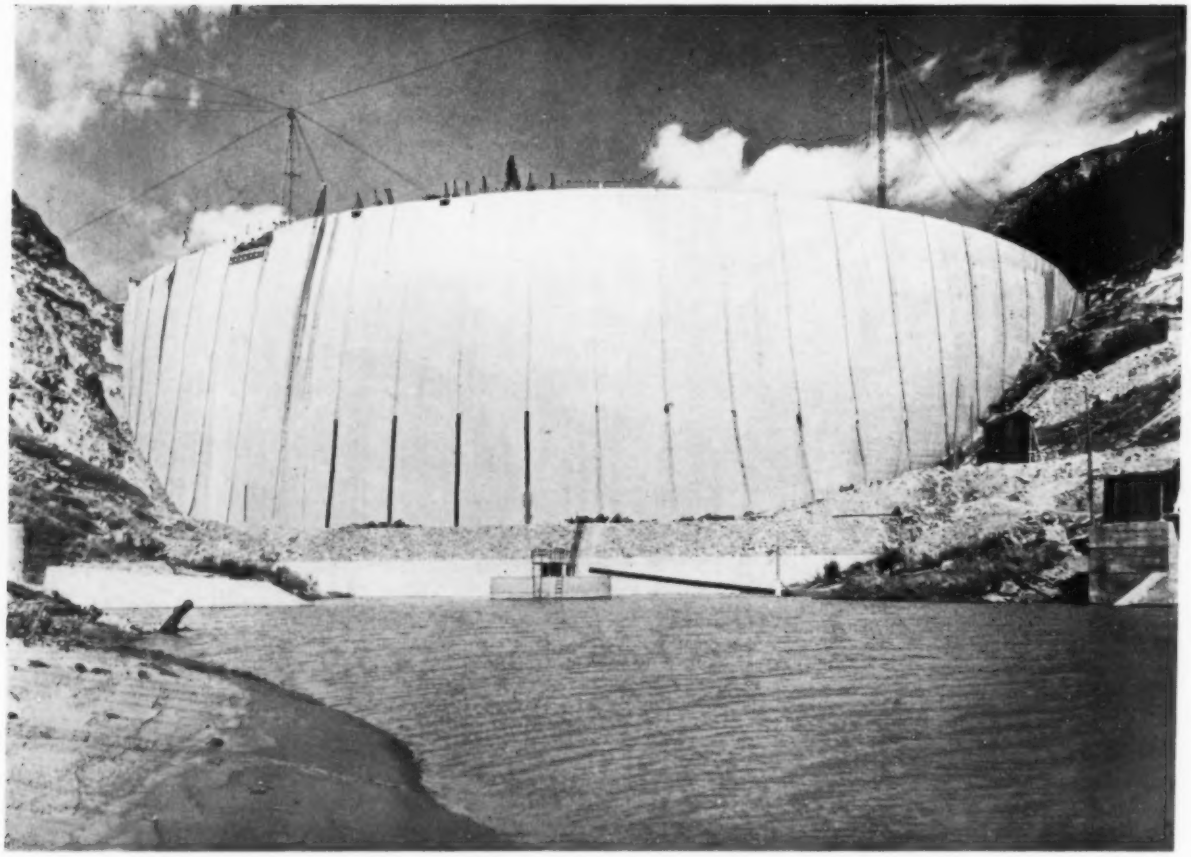
PNEUMATIC EQUIPMENT

pays . . . with its life

HOLMAN BROS. LTD., CAMBORNE, ENGLAND
The Holman Organisation is world-wide. It includes the Climax Rock Drill & Engineering Works Ltd., and has agents, branches and technical representatives throughout the United Kingdom and in 84 other countries.
Telephone: Camborne 2275 (10 lines). Telegrams: Airdrill, Telex, Camborne. London Office: 44 Brook Street, W.1. Telephone: Hyde Park 9444

HJ25



BEAUREGARD DAM ON THE DORA DI VALGRISANCHE RIVER · ITALIAN ALPS
AT EL. 5,810 ft. a.s.l. **1953 - 1957**

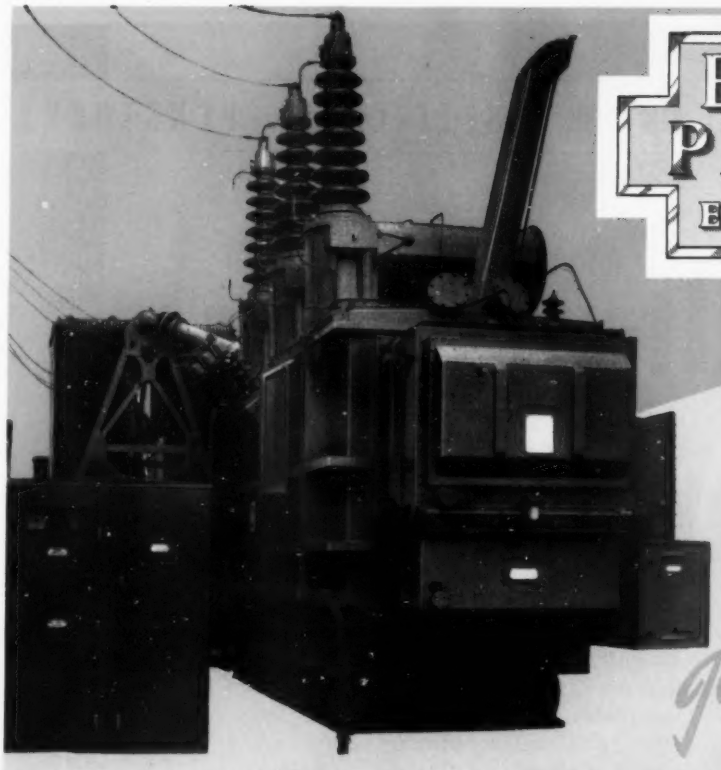
PRINCIPAL: **S.I.P.** SOCIETÀ IDROELETTRICA PIEMONTE - TURIN

TYPE: ARCH GRAVITY - MAX HEIGHT: 440 ft. - CREST LENGTH: 1,280 ft. - VOLUME: 660,000 cu. yds.

DOTT. ING G. TORNO & C.S.P.A

BUILDING & CIVIL ENGINEERING CONTRACTORS & CONSULTANTS

7, VIA ALBRICCI, **MILAN, ITALY** - CABLE ADDRESS: **IDROTORNO**



BRUCE PEEBLES
EDINBURGH

45 MVA 132/33 kV transformer for the Central Electricity Authority

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OF THE ELECTRICAL INDUSTRY WITH OVER 50 YEARS' MANUFACTURING EXPERIENCE.

Activities embrace a wide variety of manufacture ranging from heavy rotating plant for the generation and conversion of electrical energy to motors for every sphere of industry: transformers of well over 100 MVA for 275 kV service to the smallest unit for distribution schemes and rural electrification; and complete rectifier sub-station plant.

For generations the name of Bruce Peebles has been famous for the manufacture of electrical power plant. Throughout its whole history the Company has ever been progressive, and its pioneering work has played an important role in the evolution of the present-day electrical age.

14,000 kVA Hydro-Electric generator for Norway

BRUCE PEEBLES & CO. LTD. EDINBURGH. SCOTLAND

A. O. SMITH MULTI-LAYER PENSTOCKS

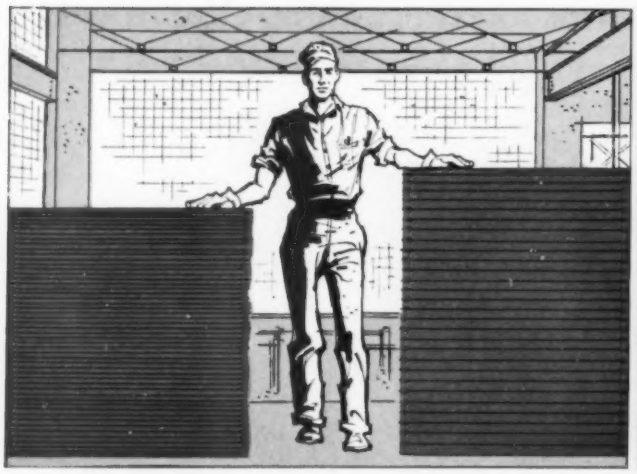
How built-up walls cut down costs

Savings start—then grow, the moment A. O. Smith MULTI-LAYER penstocks are installed. Ideally suited for high hydrostatic pressures, MULTI-LAYER's remarkable strength results from the *number* and *type* of built-up thin steel plates required to handle your job.

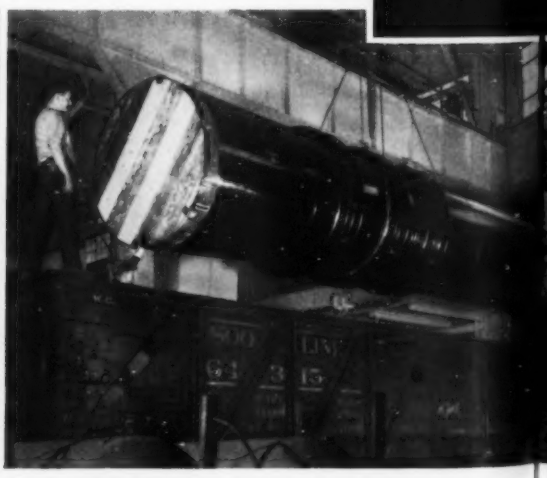
Critical material control such as this offers optimum safety and strength at lowest possible cost. Yet there's no practical limitation to the pressures that can be handled.

A complete selection of MULTI-LAYER sizes are available . . . small-diameter, thin-wall up to 30″ . . . larger diameters made to order including "wyes," "bends," and other "specials."

For aid in solving penstock problems, backed by unlimited research and production facilities, write A. O. Smith International S. A., Administrative Offices: P. O. Box 331, Milwaukee 1, Wis., U.S.A.



MULTI-LAYER saves up to 15% in amount of steel required for conventional *thick* plate, single wall penstocks of the same diameter. MULTI-LAYER *saves tonnage.* Layers of thin, high-tensile strength steel plate are progressively wrapped, tightened and welded around the core.



MULTI-LAYER saves in freight and cargo costs. A. O. Smith MULTI-LAYER penstocks weigh less . . . shipping costs are substantially cut. Especially important when jobs are located in remote areas. Handling and erection are faster, easier at the job site.

Manufacture of MULTI-LAYER pipe section. This modern A. O. Smith construction results in lighter, safer and more easily welded high-head penstock sections, as compared to ordinary single wall construction.

MULTI-LAYER saves by eliminating costly stress-relieving of welds in the field. Residual stresses in welds are negligible. MULTI-LAYER requires no bothersome, time-consuming handling of sections into and out of stress-relieving furnaces.

Through research A.O. Smith *... a better way*

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EIMCO 105
TRACTOR EXCAVATOR

For rock loading, ore handling, in mines and tunnels, on construction jobs or in steel plants, in fact wherever the call is for high speed, dependable loading, the answer is the EIMCO 105 Tractor Excavator. No matter what the conditions, the tough, rugged 105 can take it.

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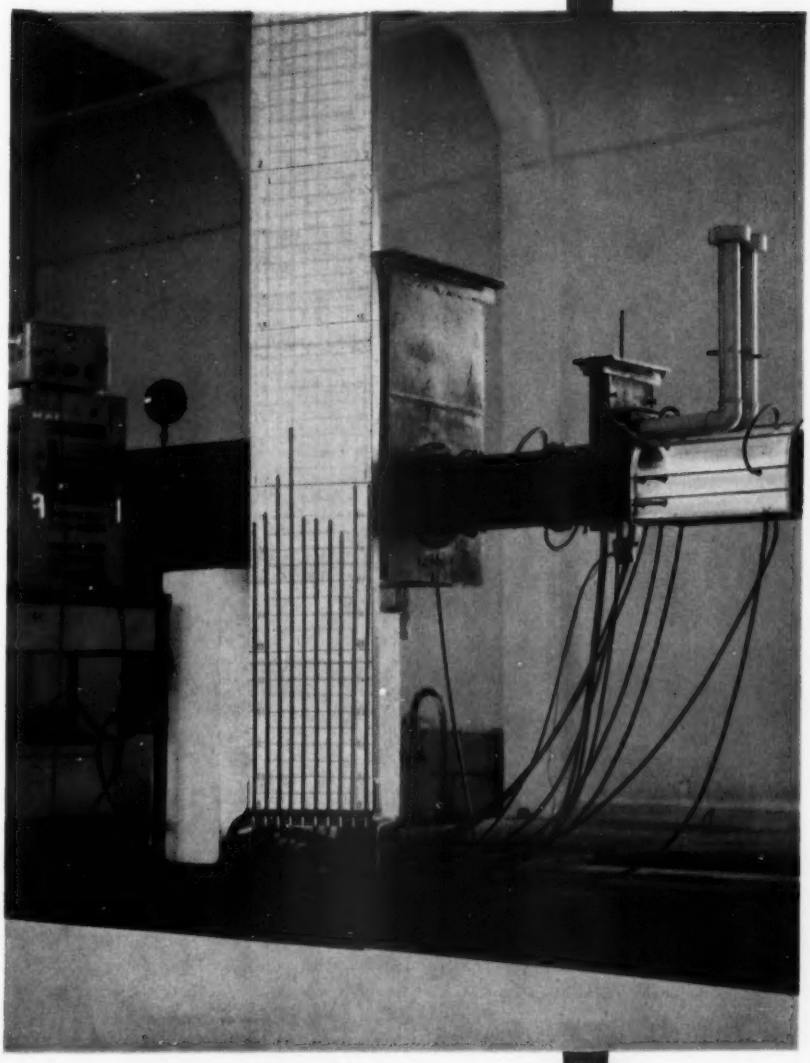
1357

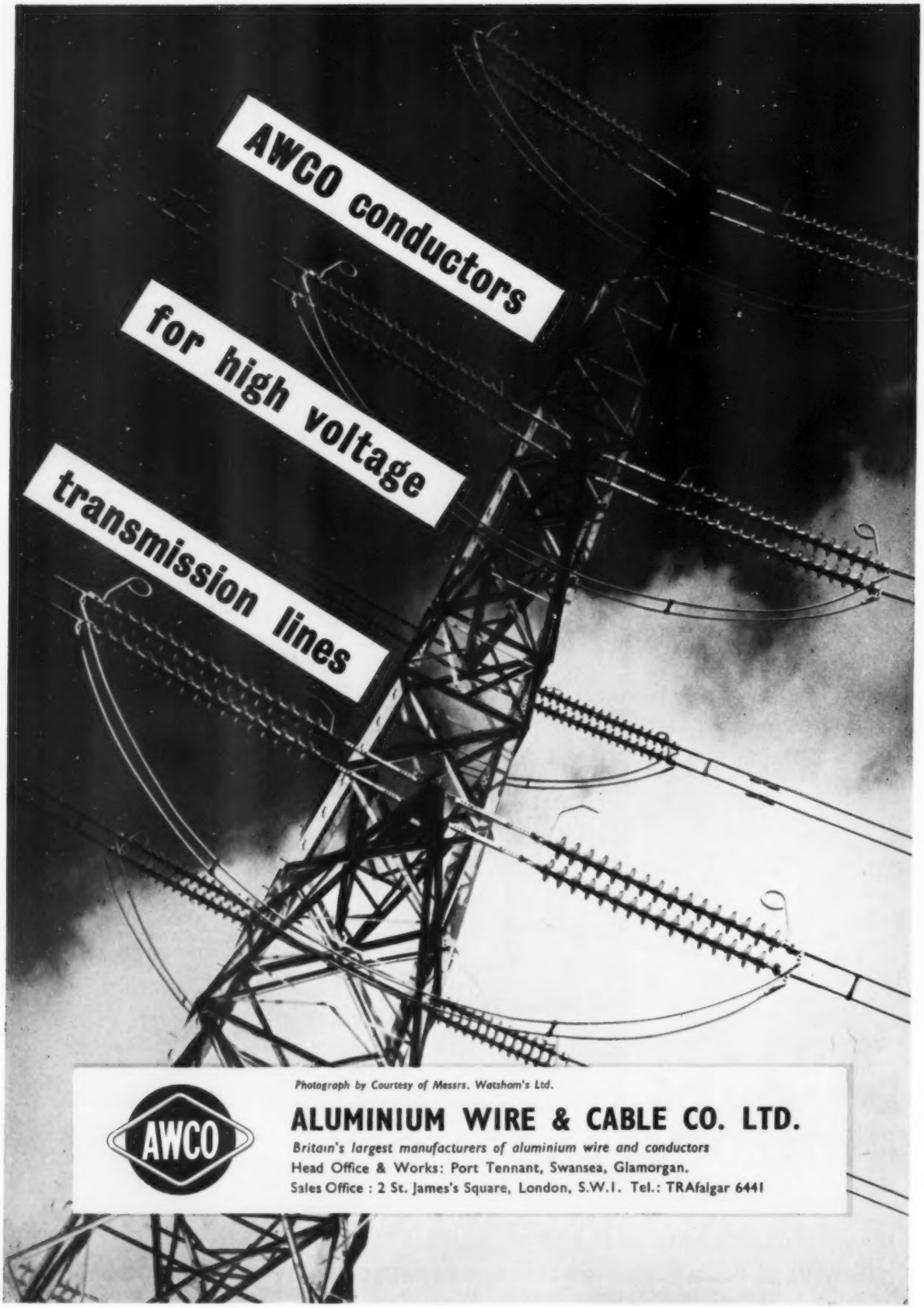
From model tests on hydraulic steel structures substantial knowledge is derived. The picture shows a test being carried out for the deep sluice gates of the Bhakra Dam (India), which are being checked with a view to determine whether or not they are free from cavitation and vibration and sufficiently aerated.



M·A·N

HYDRAULIC LABORATORY

MASCHINENFABRIK AUGSBURG-NÜRNBERG AG GUSTAVSBURG WORKS
GUSTAVSBURG/HESSEN (GERMANY) REPRESENTATIVES IN ALL COUNTRIES



Photograph by Courtesy of Messrs. Watsham's Ltd.

AWCO

ALUMINIUM WIRE & CABLE CO. LTD.

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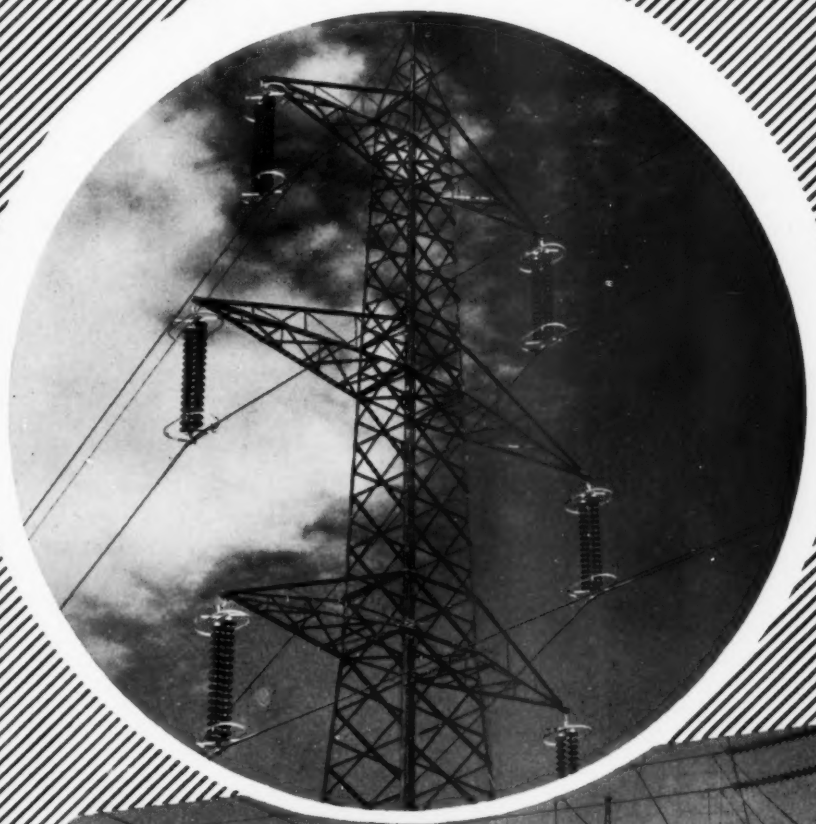
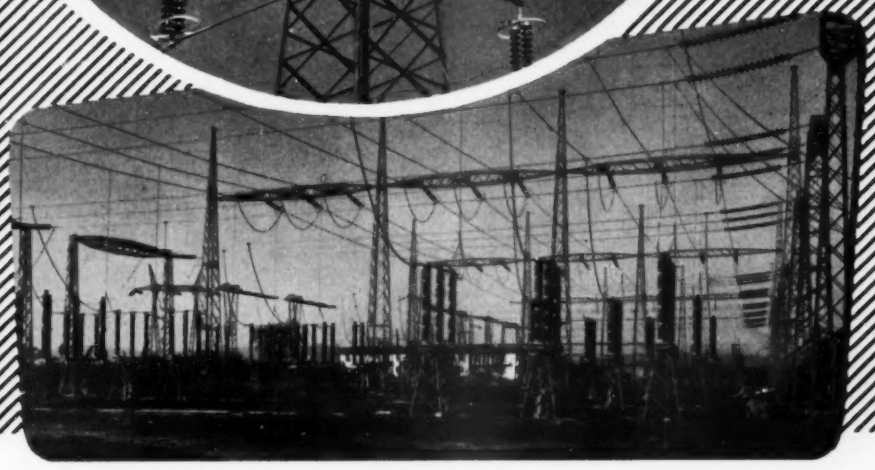
AP 24

SALVI





For 30 years Messrs. A. Salvi and Company, Milano, Italy, have specialized in the design and manufacture of complete equipment for Overhead Transmission Lines, including Compression Dead End Assemblies and Joints.
The Works of the Salvi Company are engaged exclusively in the production of high grade fittings for High Voltage Transmission Systems, up to and including voltages of 220/380 KV, and for all sizes of Copper, A.C.S.R. and Aluminium Alloy Conductors.

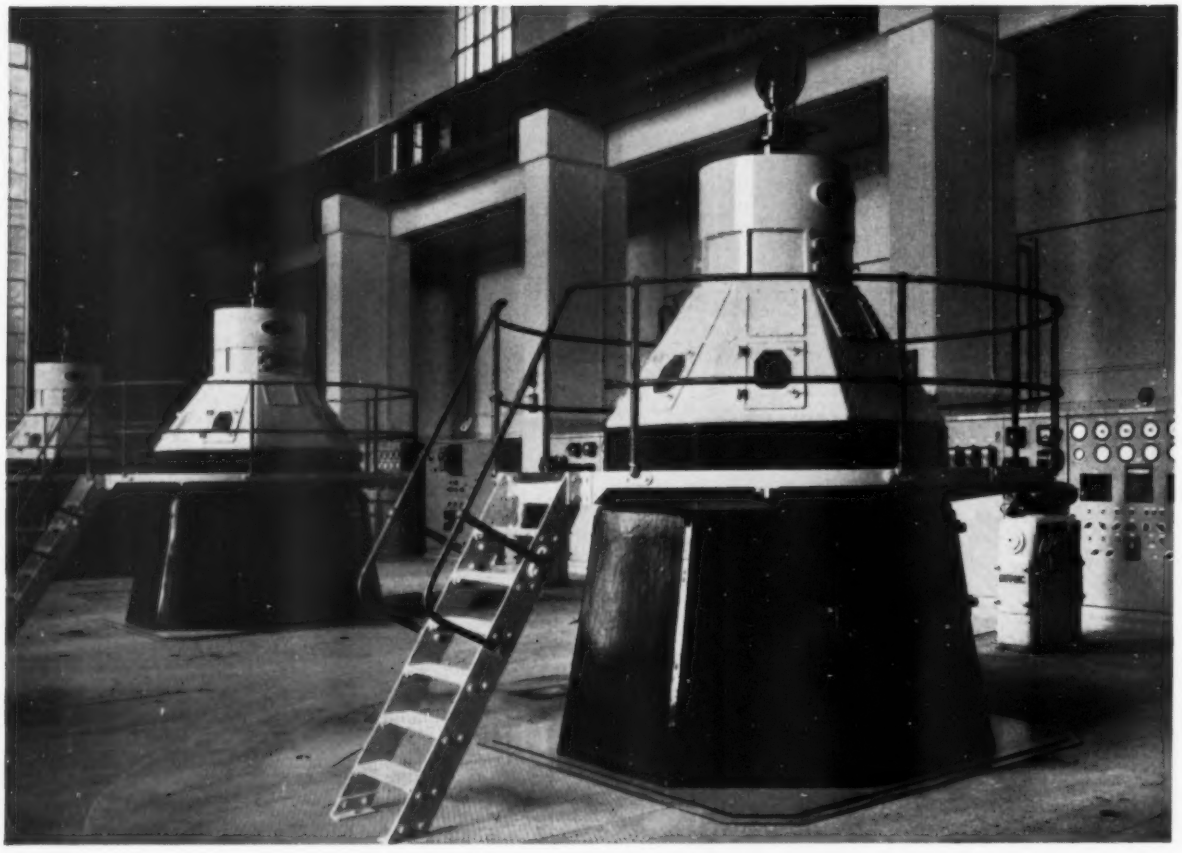
SOLE REPRESENTATIVES IN THE UNITED KINGDOM AND THROUGHOUT ALL DOMINION COUNTRIES
(EXCEPT AUSTRALIA AND NEW ZEALAND) AND BRITISH COLONIES AND PROTECTORATES

THE ENGLISH SALVI COMPANY LTD., 11 Kensington Church St., London, W.8

Telephones: WEStern 8857 and 4412 Cables: ENSALVICO LONDON

Highland water power

This is Errochty power station on the shore of Loch Tummel. It is the largest generating station in the Tummel-Garry Scheme of the North of Scotland Hydro-Electric Board, and houses three 25 MW vertical-shaft hydro-alternators built and installed by G.E.C. Auxiliary motors and most of the control gear in the station were also supplied by G.E.C.



G.E.C.

HYDRO-ELECTRIC PLANT

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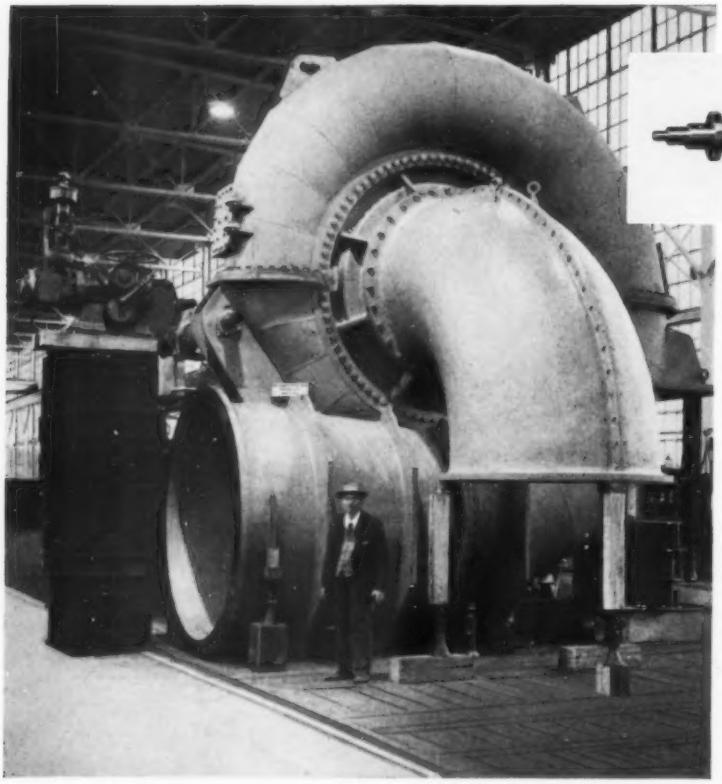
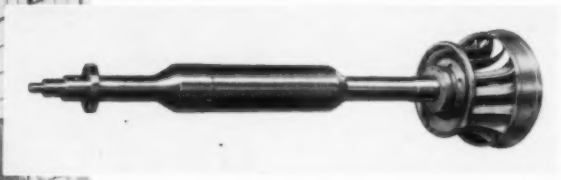
P. O. BOX 308 BRESCIA - Tel. 36.700 BRESCIA - Cable: ATUB - BRESCIA - ITALY

LEFFEL BUILDS GIANT HORIZONTAL TURBINE FOR PLEASANT VALLEY

The low net head of 68 ft. at the Pleasant Valley Power Plant near Los Angeles required the design and construction by Leffel of a giant, horizontal spiral case turbine unit. This turbine, rated to develop 3,520 H.P. under the net head of 68 ft. at a speed of 257 R.P.M., drives a horizontal generator. A common shaft carries both the generator rotor and the stainless steel runner. A synchronous by-pass valve allows adjustment of flow for both turbine and by-pass discharge to meet water passage requirements. Photographs here show this giant turbine in various stages of production at the modern Leffel plant.





Leffel has the technical know-how and modern plant facilities to design and construct efficient, economical, rugged turbines of most types and capacities. And Leffel provides fast, complete service. Field engineers are available to assist you in the original planning of your project, and to help you with the actual installation of your turbine.

If you're planning a new project, or the rehabilitation or expansion of old facilities, and you want fast, complete service, contact Leffel, producers of top performing turbines. Mail the coupon below, today, for complete information.

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ESCHER WYSS STORAGE PUMPS

Some recent deliveries:

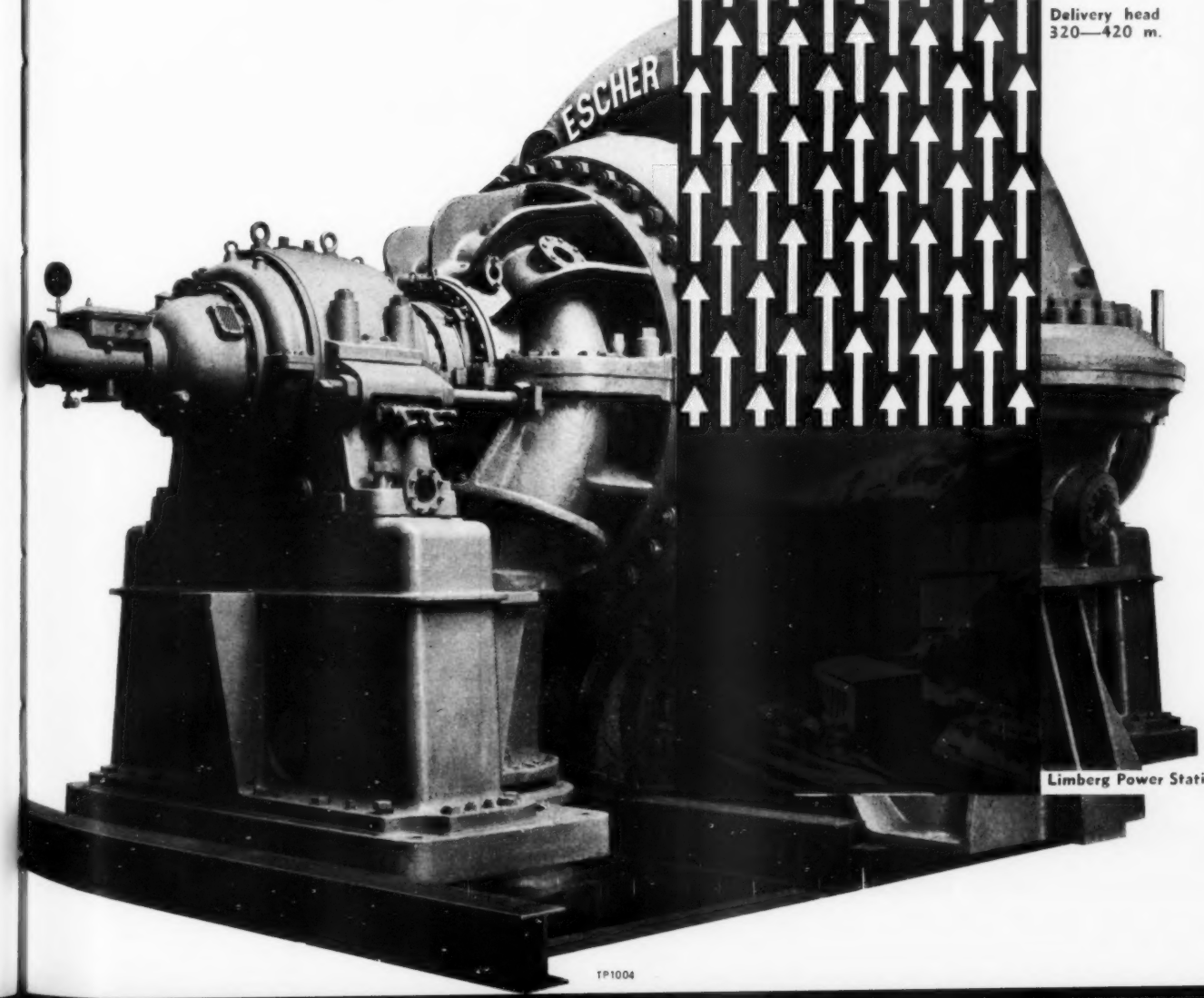
Häusern (Schluchsee)	2 pumps of	32 600 HP
Cotilia-Turano	2 pumps of	37 600 HP
Witznau (Schluchsee)	2 pumps of	40 000 HP
Hamburg	3 pumps of	43 600 HP
Lünersee	2 pumps of	57 600 HP
Provvidenza	2 pumps of	62 700 HP
Limberg	2 pumps of	**85 000** HP

ESCHER WYSS LTD ZURICH

(SWITZERLAND)

Storage lakes of Mooserboden and Wasserfallboden

Delivery head 320—420 m.



Limberg Power Station

TP1004

In Switzerland and the world over

Bucyrus-Erie excavators are consistently preferred

Five 54-B Bucyrus-Erie 2½ cubic yard Ward-Leonard electric shovels loading blasted moraine rock for use on the huge concrete dam at Grande Dixence, Switzerland, nearly 9,000 ft. above sea-level; once more, and in still another country, proving that Bucyrus-Erie excavators are preferred for maximum output and reliability in tough conditions.

BUCYRUS-ERIE COMPANY
South Milwaukee, Wisconsin, U.S.A.
RUSTON-BUCYRUS LIMITED, LINCOLN, ENGLAND

BUCYRUS ERIE

VeVeY

Complete

equipment for Hydro-electric Power Plants

Turbines

governors

penstocks

valves

travelling cranes

Ateliers de Constructions Mécaniques de Vevey S.A.

VEVEY 1471 E

In Switzerland and the world over

Bucyrus-Erie excavators are consistently preferred

Five 54-B Bucyrus-Erie 2½ cubic yard Ward-Leonard electric shovels loading blasted moraine rock for use on the huge concrete dam at Grande Dixence, Switzerland, nearly 9,000 ft. above sea-level; once more, and in still another country, proving that Bucyrus-Erie excavators are preferred for maximum output and reliability in tough conditions.

BUCYRUS-ERIE COMPANY
South Milwaukee, Wisconsin, U.S.A.
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BUCYRUS ERIE

VeVeY

Complete

equipment for Hydro-electric Power Plants

Turbines

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Ateliers de Constructions Mécaniques de Vevey S.A.

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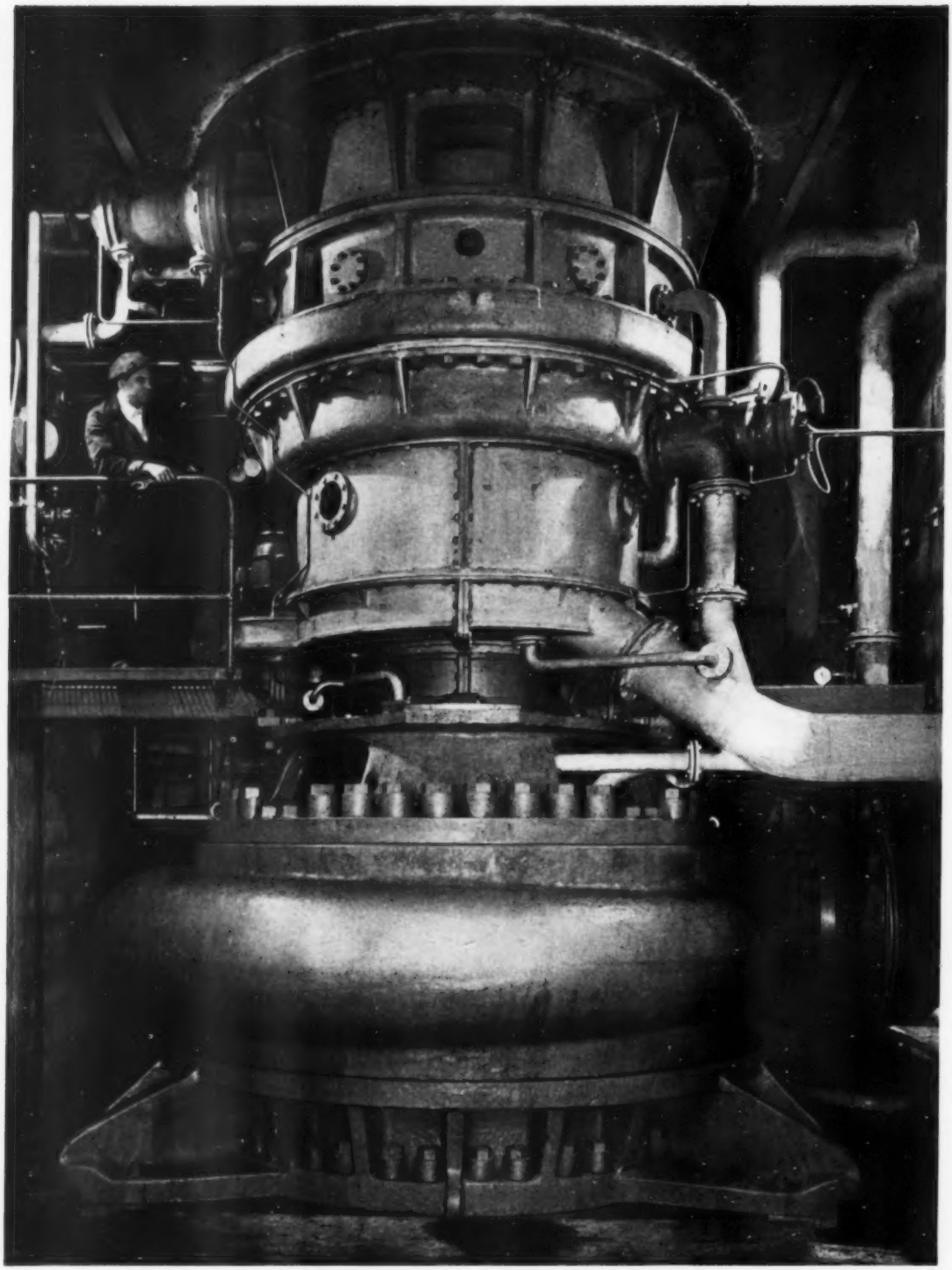
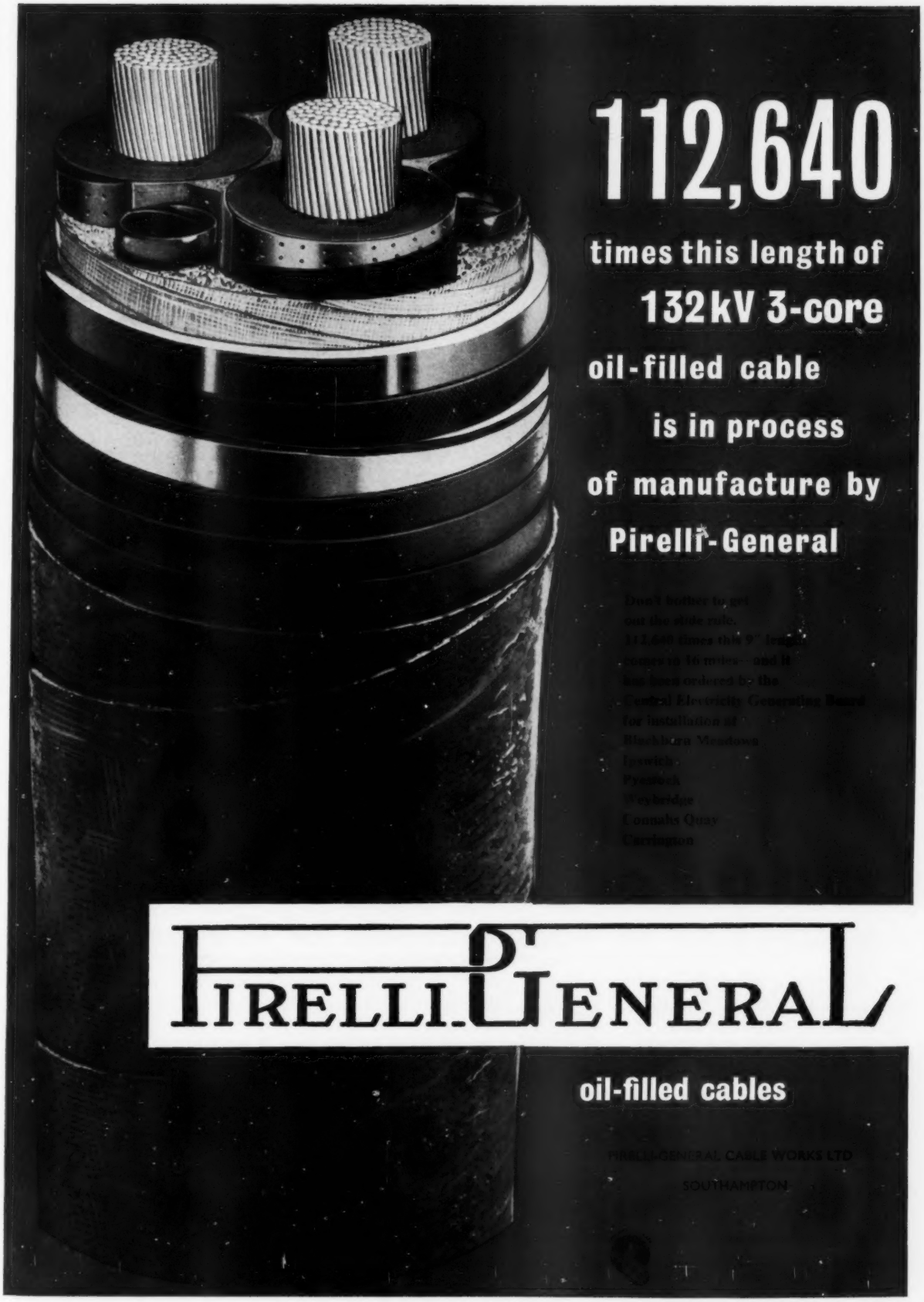


Within 25 seconds the torque-converter driven 43,000 kW pump, starting from rest, operates at full capacity.

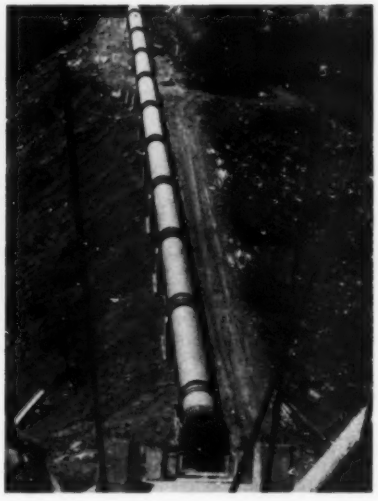
In the Lünersee Pumped Storage Station, in November, 1957, the first of the 2 all-Voith sets went into successful operation. Each set comprises a 4-jet 46,000 kW Voith Impulse Turbine, a 5-stage 43,000 kW Voith Storage Pump, and a Voith Torque Converter with sliding gear coupling which starts and runs the pump up to synchronous speed for coupling to the motor-generator. Voith Torque Converters equip also the other three sets of the Lünersee Pumped Storage Scheme.

J. M. VOITH GMBH · HEIDENHEIM (BRENZ) · GERMANY


112,640
times this length of
132kV 3-core
oil-filled cable
is in process
of manufacture by
Pirelli-General
PIRELLI-GENERAL
oil-filled cables
PIRELLI-GENERAL CABLE WORKS LTD
SOUTHAMPTON

CALIFORNIA-OREGON POWER COMPANY...

another 100% Dresser-Coupled penstock



Two views of Yamsay, Oregon, uncovered penstock of California-Oregon Power Company. This is a 100% Dresser-Coupled line...3847 ft. long, 55 ft. sections,from 126-in. diameter at inlet to 88-in. at outlet. Wall thickness varies from ¼ inch plate to 1-7/16 inch.

Each Dresser Coupling is engineered to meet the pressure at each portion of the penstock

Near Yamsay, Oregon, you'll find another impressive argument for using steel-pipe penstocks and Dresser Couplings. This penstock (described above) is owned by The California-Oregon Power Company, was engineered by Pioneer Service and Engineering Co. The line is 100 percent Dresser-Coupled...the only type of joint which could be individually tailored to the pressure requirements at each portion of the penstock.

UP TO 25% LIGHTER

The Dresser method saves money by permitting the use of lighter wall, high tensile steel pipe. Weight savings can amount to 25 percent... resulting in lower freight and handling costs, lighter equipment on the job. There are no fussy lining-up operations as with welding and riveting. The flexibility of the Dresser Coupling compensates for slight misalignments caused by grade variations. With the Dresser method, you get a stress-free line, bottle-tight for life.

If you'd like to see technical data on a number of other Dresser-Coupled penstock installations, write for illustrated brochure. Before you draw up specifications, make sure you have all the facts on steel pipe joined with Dresser Couplings.

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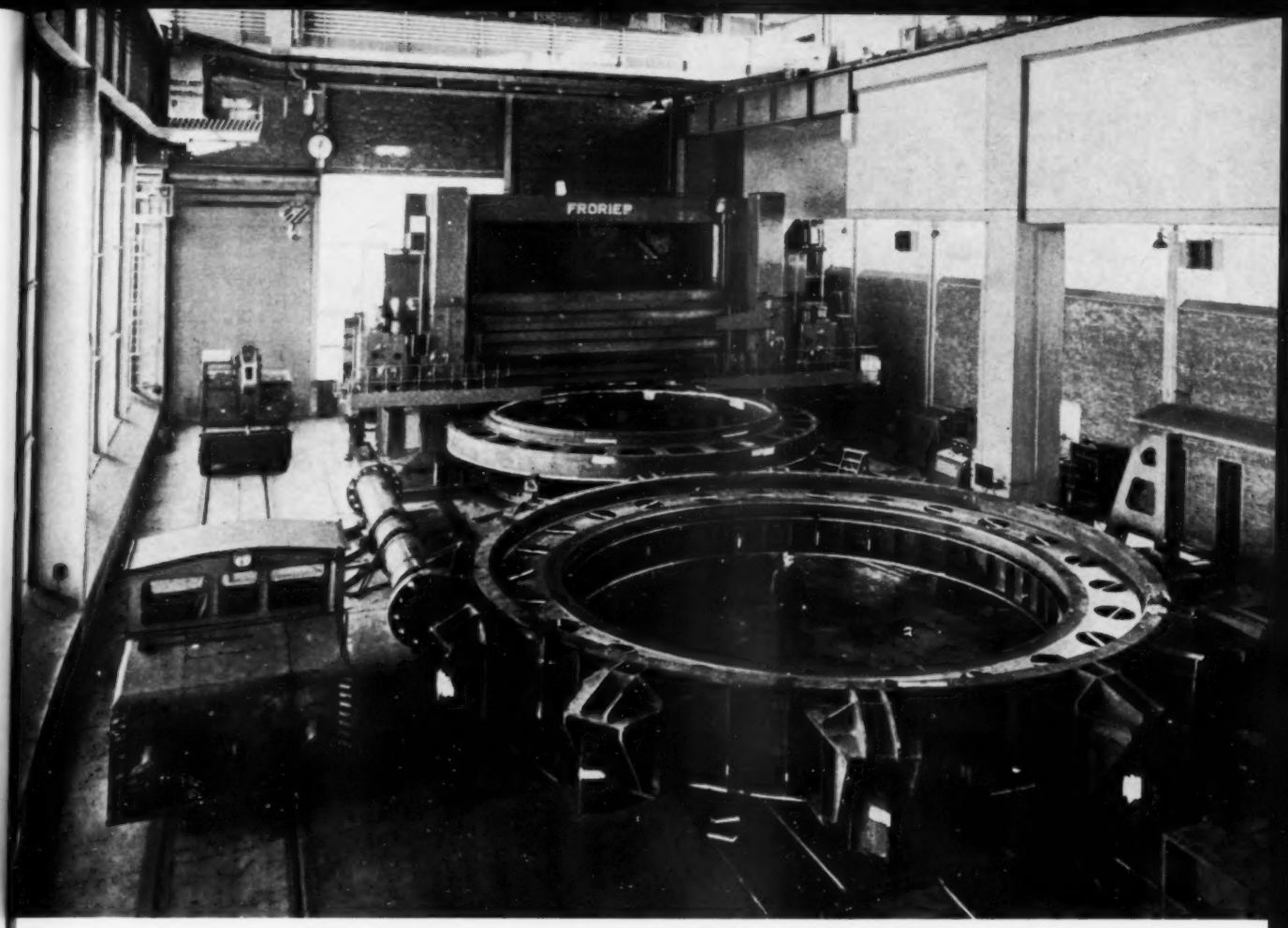
MANUFACTURING DIVISION

ONE OF THE DRESSER INDUSTRIES



Kaplan Turbines of gigantic size

The KMW Works at Kristinehamn are now hard at work manufacturing the Kaplan turbines for Järkvissle—the last power station on Sweden's most exploited river. Nearly everyone in Sweden will know we refer to the River Indal although they may not be aware that 80% of the power stations on this river are equipped with KMW turbines. This means that 12 of the 15 stations have KMW turbines or, in other words, 1½ million KMW-horsepower harness the mighty flow of the Indal.

But to revert to Järkvissle, the picture shows parts of the guide apparatus for the first unit. The vertical turning mill in the background which weighs 525 tons and has a power consumption of 200 H.P., can take workpieces up to 50 ft. in diameter. This enormous capacity is necessary to deal with large components as for the Järkvissle turbines.

These turbines will each develop a normal output of 59,500 H.P. at a head of 45 ft. The runner will be one of the largest in the world, having a diameter of 25 ft. Both turbines are planned to be in operation by the end of 1959 and the Swedish Power Board will then add another to its string of power stations on this river system.

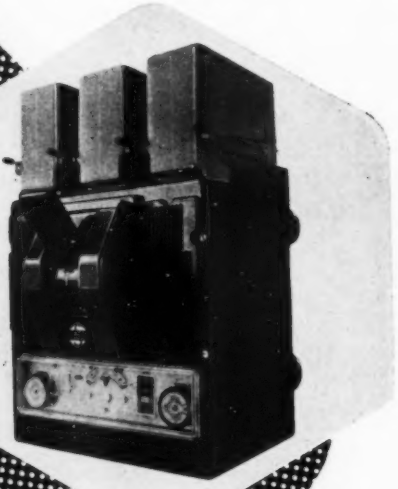
KMW

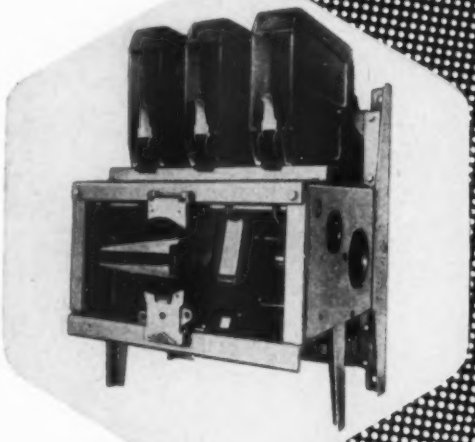
AB KARLSTADS MEKANISKA WERKSTAD KARLSTAD SWEDEN

Representatives in Canada: A. Johnson & Co (Canada) Ltd. 607 Shell Tower Building, Montreal 2

Circuit breaker type "Z 2„
Rated voltage 500 V
Rated current up to 600 A
Breaking capacity 20 kA
at 500 V a. c.

Circuit breaker type "P„
Rated voltage 500 V
Rated current up to 4000 A
Breaking capacity up to 50 kA





Circuit breaker type "MPR„
Rated voltage up to 30 kV
Rated current up to 800 A
Breaking capacity up to 500 MVA

SACE 114

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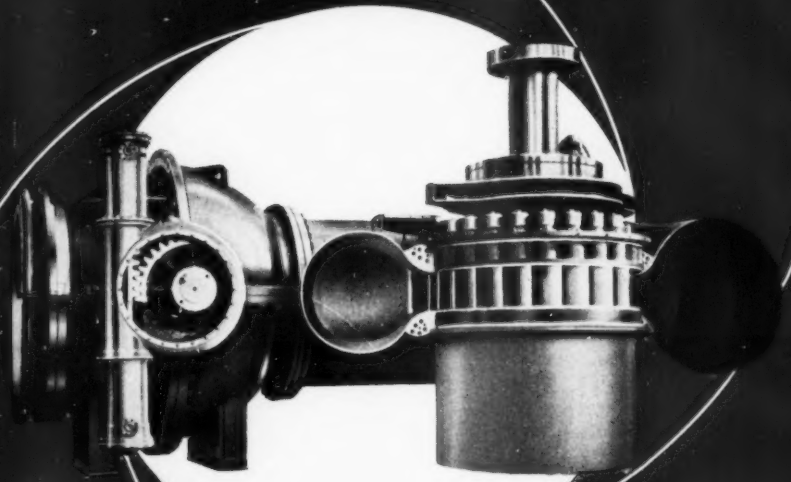

Turbines of the Francis, Kaplan and Pelton type for various heads and outputs, transformers, generators, outdoor and indoor switch-gear, control-rooms, etc.

The world-known SKODA and ČKD trade-marks guarantee the first-class technical design and quality of equipment supplied by us. We give integral guarantees for complete deliveries.

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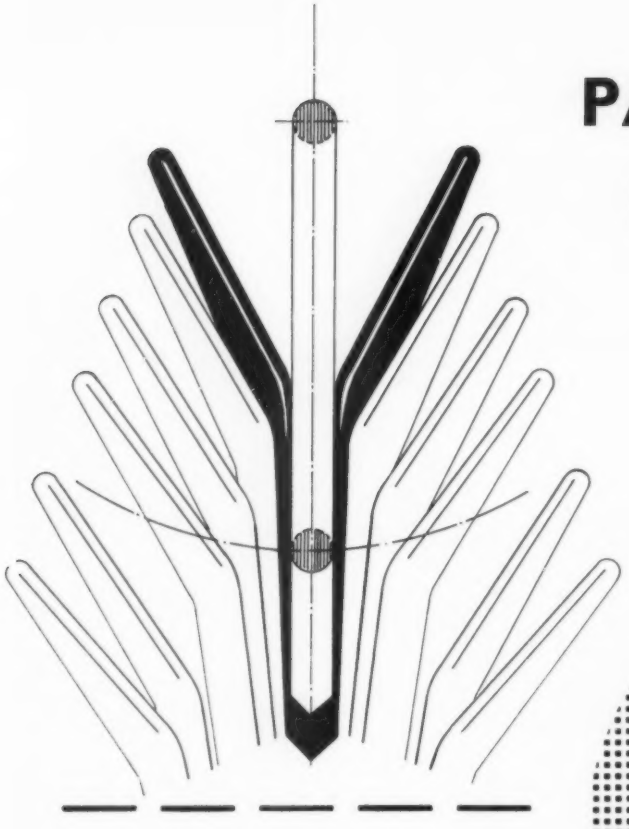
PANTOGRAPH ISOLATORS



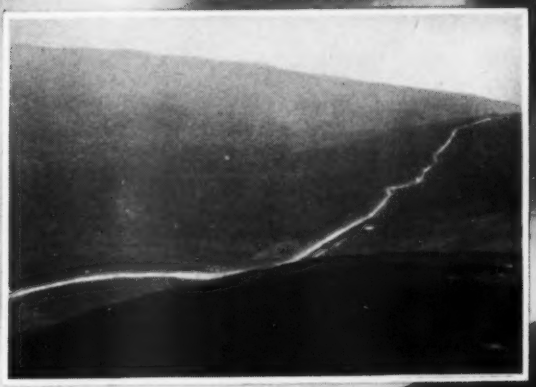
SCARPA & MAGNANO pantograph isolators are fitted with a special flexible bridle, suspended from the line conductor, which compensates automatically for transverse oscillations and also for vertical movements induced by changes of temperature. Owing to the compensating action of this bridle and to the long gripping surfaces of the pincer-type moving contacts, SCARPA & MAGNANO pantograph isolators can be employed with complete safety even in the middle of a long conductor span.

When an isolator is closed, the pressure of the special bridle and the high degree of flexibility of the pantograph linkwork enable the isolator to adapt itself to line oscillations over a wide range without subjecting the insulator parts to excessive stresses.

Savona - Italy

SCARPA & MAGNANO

The Contractor shall provide all necessary temporary access...



The problem varies from site to site—here are some 40 miles of access roads built complete with bridges by The Mitchell Construction Company in Glen Almond, Glen Tarken and Glen Lednock for development of the St. Fillans Section of the North of Scotland Hydro-Electric Board's Breadalbane Scheme.

CONSULTING ENGINEERS

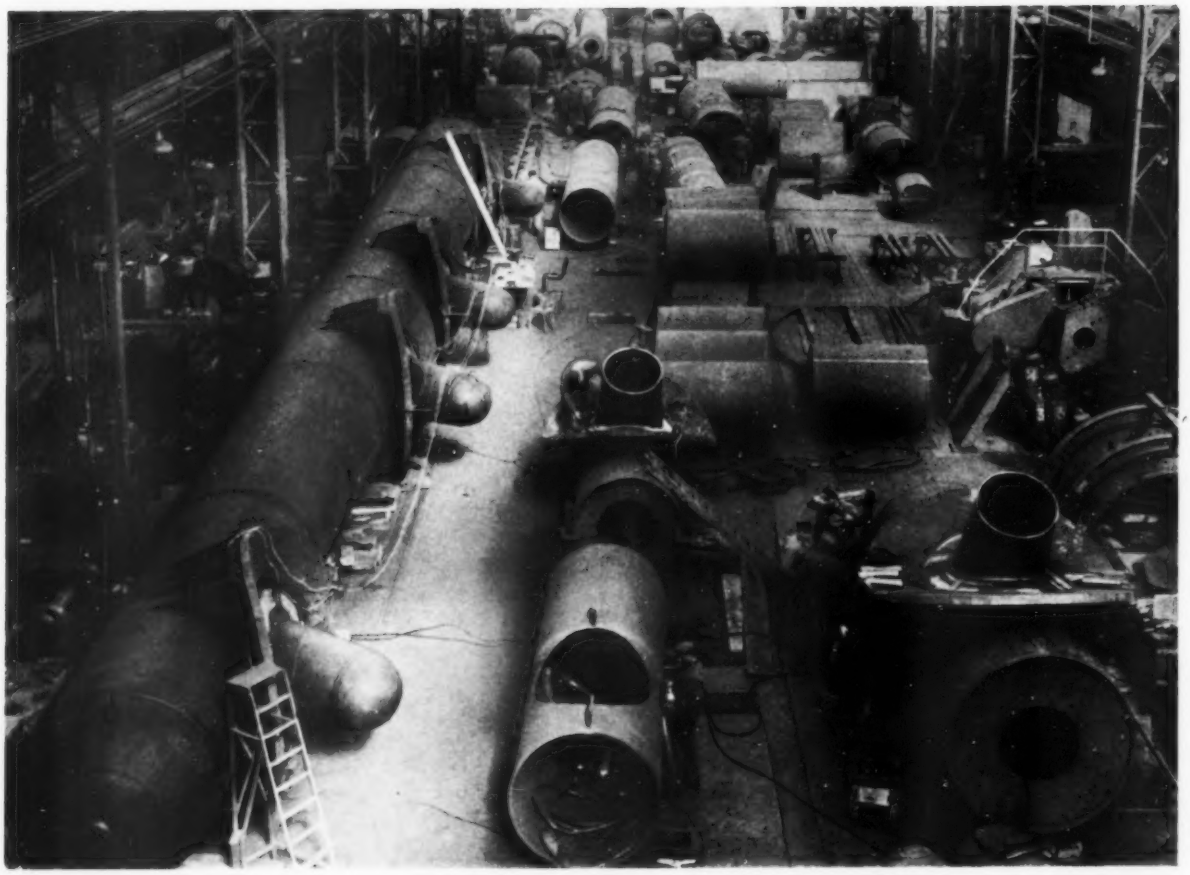
Sir M. Macdonald & Partners

THE MITCHELL CONSTRUCTION COMPANY

WHARF WORKS PETERBOROUGH

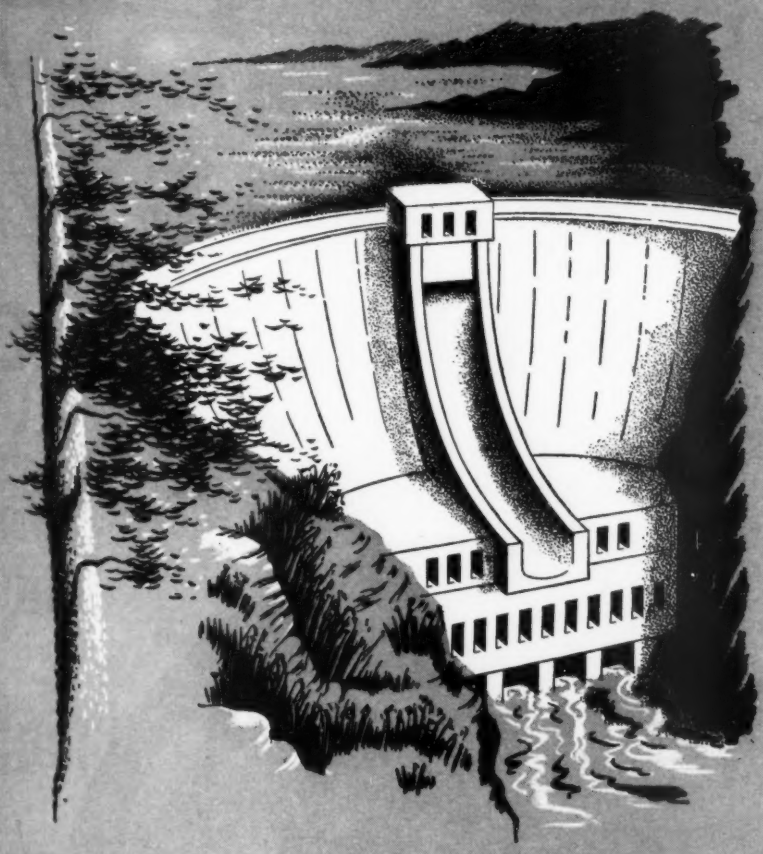
MITCHELL

Penstocks, pressure shafts linings,
Substation steel structures
Gantry and overhead travelling cranes
Pylons, water gates



Downstream portion of the Grande Dixence Fionnay Power Station distribution pipe during tensometric shop tests. Max. wall thickness 52 mm., service pressure 96 at., test pressure 121 at.

GIOVANOLA **Monthey - Switzerland**



FERRANTI

Transformers for Hydro-Electric Schemes

As specialists in the manufacture of transformers for more than 65 years, FERRANTI LTD. have been associated with many of the world's largest hydro-electric schemes.

More recent achievements include contracts for over 4,000,000 kVA of large high voltage power transformers, among which are :-

CENTRAL AFRICA

Two 120,000 kVA and ten 60,000 kVA 330,000 volts three-phase Transformers have been ordered by the Central African Federation Power Board for the Kariba Hydro Electric Scheme. This is the largest overseas transformer contract ever to be placed in the United Kingdom.

CANADA

Seven 71,000 kVA, 301,400 volt single-phase Ferranti generator transformers and six 37,000 kVA, 275,000 volt step-down Ferranti transformers have been ordered by the Aluminum Company of Canada Ltd. for the Alcan Project at Kemano and Kitimat, British Columbia. Four of the generator transformers and all of the supply transformers are now in commission.

U.S.A.

GARRISON DAM PROJECT Nine 33,333 kVA, 230,000 volt single-phase Ferranti transformers forming three 100,000 kVA banks have been supplied to the U.S. Army Corps of Engineers for the Garrison Dam Project, North Dakota.

McNARY DAM PROJECT Six 56,000 kVA, 230,000 volt, single-phase transformers have been ordered by the U.S. Army Corps of Engineers for the McNary Dam Project, Oregon.

DALLES DAM PROJECT The contract covers eighteen 63,000 kVA, 230 kV and three 63,000 kVA, 115 kV, single-phase transformers for the U.S. Army Corps of Engineers Dalles Dam Project, Columbia River.

NEW ZEALAND

Twenty-six Ferranti large power transformers have been ordered by the State Hydro-Electric Department of New Zealand. Thirteen 14,800 kVA, single-phase, 50 cycles, 11/220 kV transformers have been supplied to Roxburgh, and thirteen 9,259 kVA, single-phase, 50 cycles, 11/220 kV transformers have been supplied to Whakamaru.

INDIA

Three Ferranti 20,000 kVA, OFB, 3-phase, 50 cycles, 132/33-66 kV transformers with on-load tap changing gear and two Ferranti 10,000 kVA, ON/OB, 3-phase, 50 cycles, 132/33 kV transformers with on-load tap changing gear have been supplied for the Damodar Valley Power Scheme in India.

Visit our Stand No. M9 at the A.S.E.E. Exhibition, March 25th to 29th.

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Output : 6 900 HP - Head : 35 ft - Speed : 150 r.p.m

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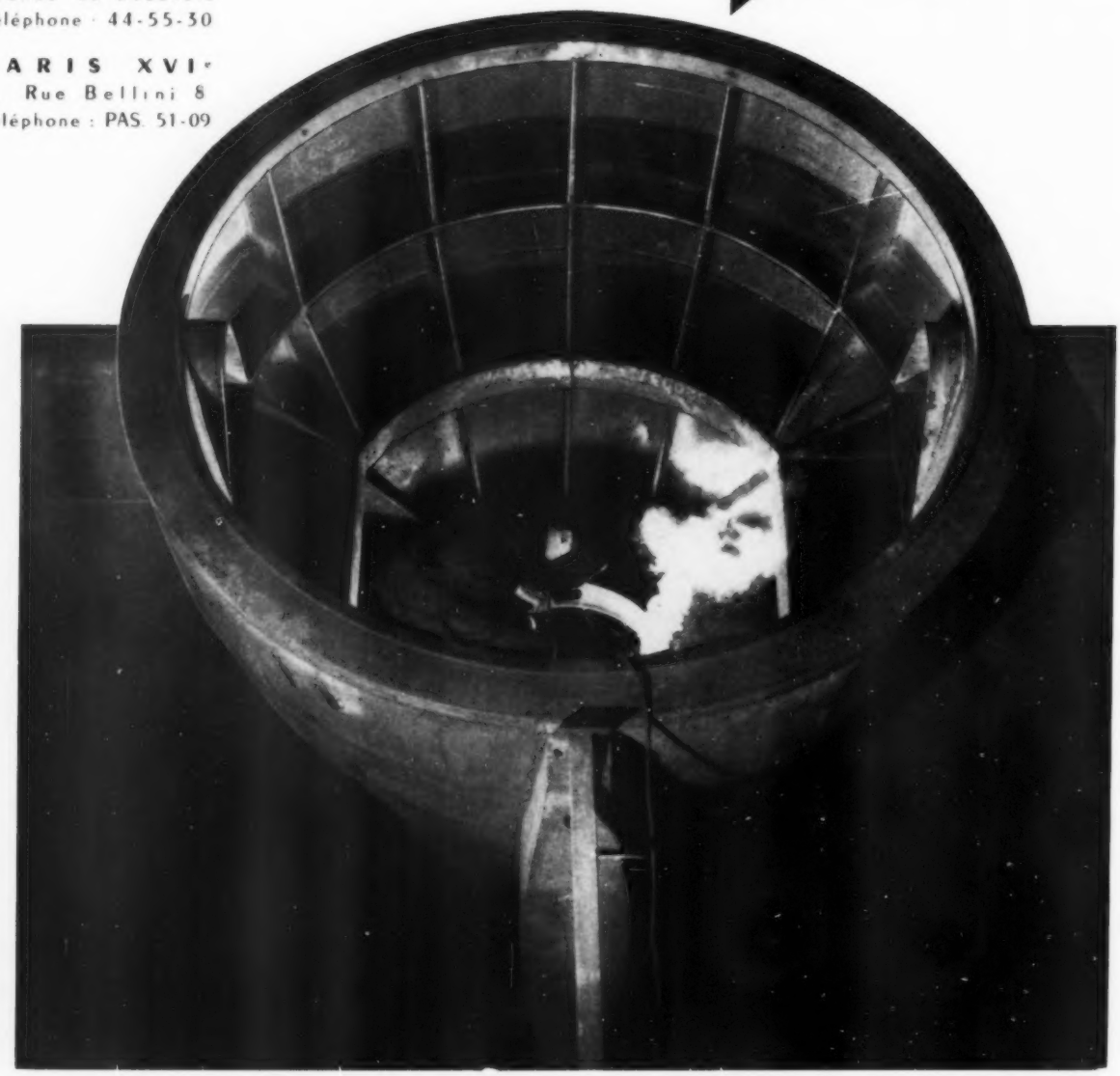
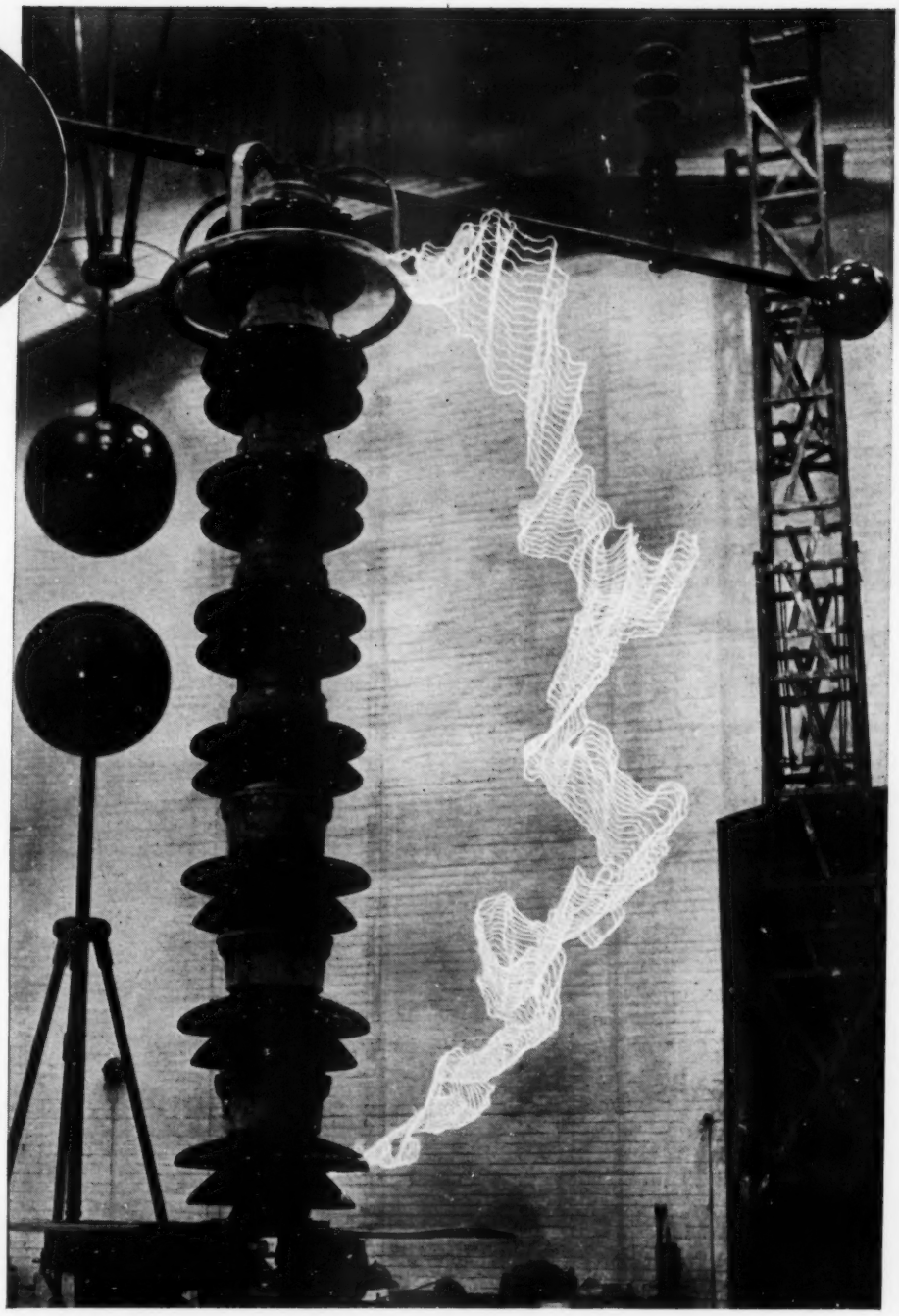


275kV. post insulators for the British Super Grid



One of the S.P.P. 8-unit post insulators for the B.E.A. 275 kV Super Grid undergoing the 50-cycle flashover test at 705 kV during the official type tests carried out at the million-volt laboratory at Stourport-on-Severn.

STEATITE & PORCELAIN PRODUCTS LTD.

Stourport-on-Severn, Worcestershire. Telephone : Stourport 2271 Telegrams : Steatain, Stourport

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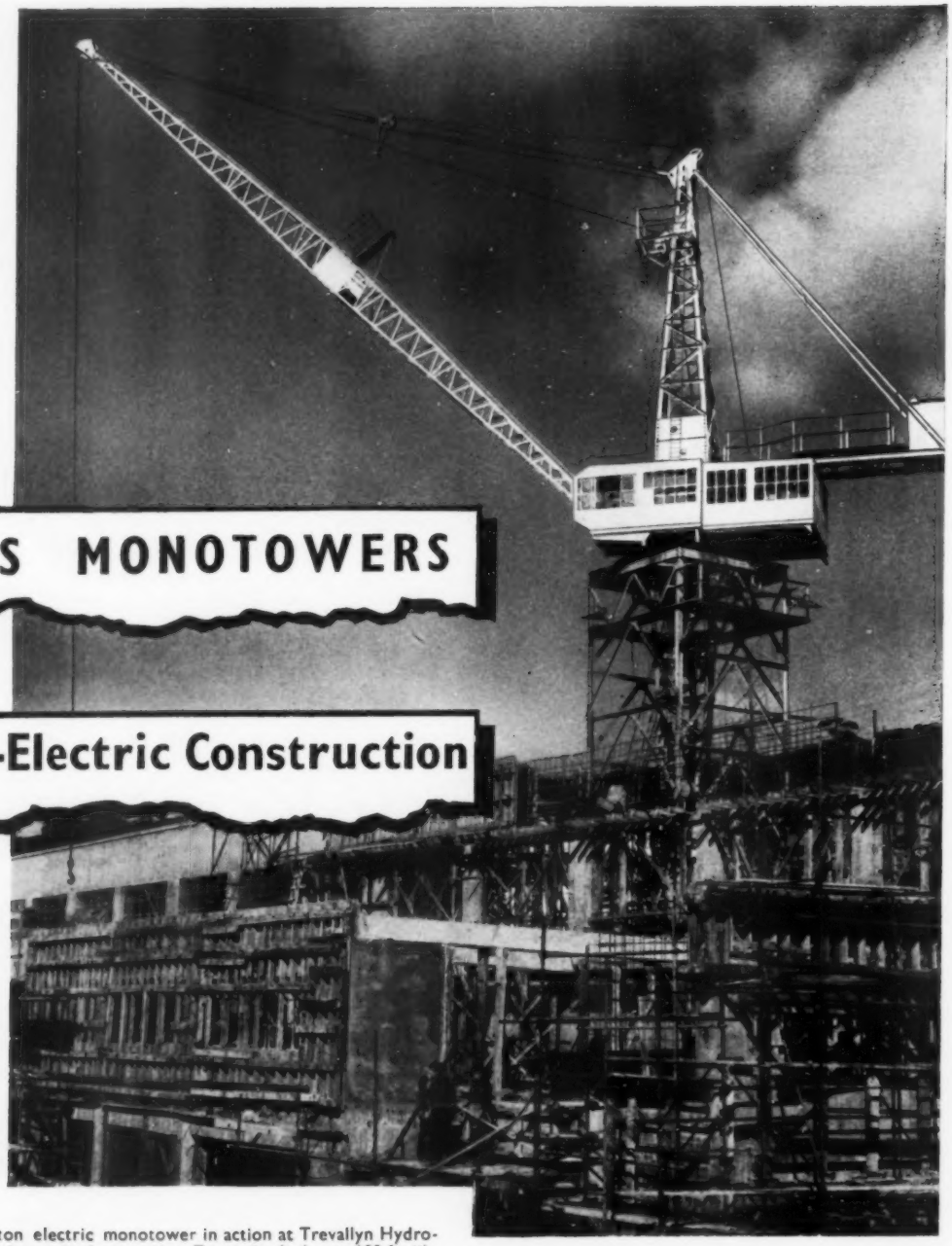

BUTTERS MONOTOWERS

in Hydro-Electric Construction

This crane is a 5 ton electric monotower in action at Trevallyn Hydro-Electric Power Station near Launceston, Tasmania. It has a 100 ft. jib, 80 ft. tower, and handles 5 tons at 75 ft. and 1¼ tons at 100 ft. radius. The ideal crane for erection of dams and high buildings generally, with all the dependability of the Butters product.

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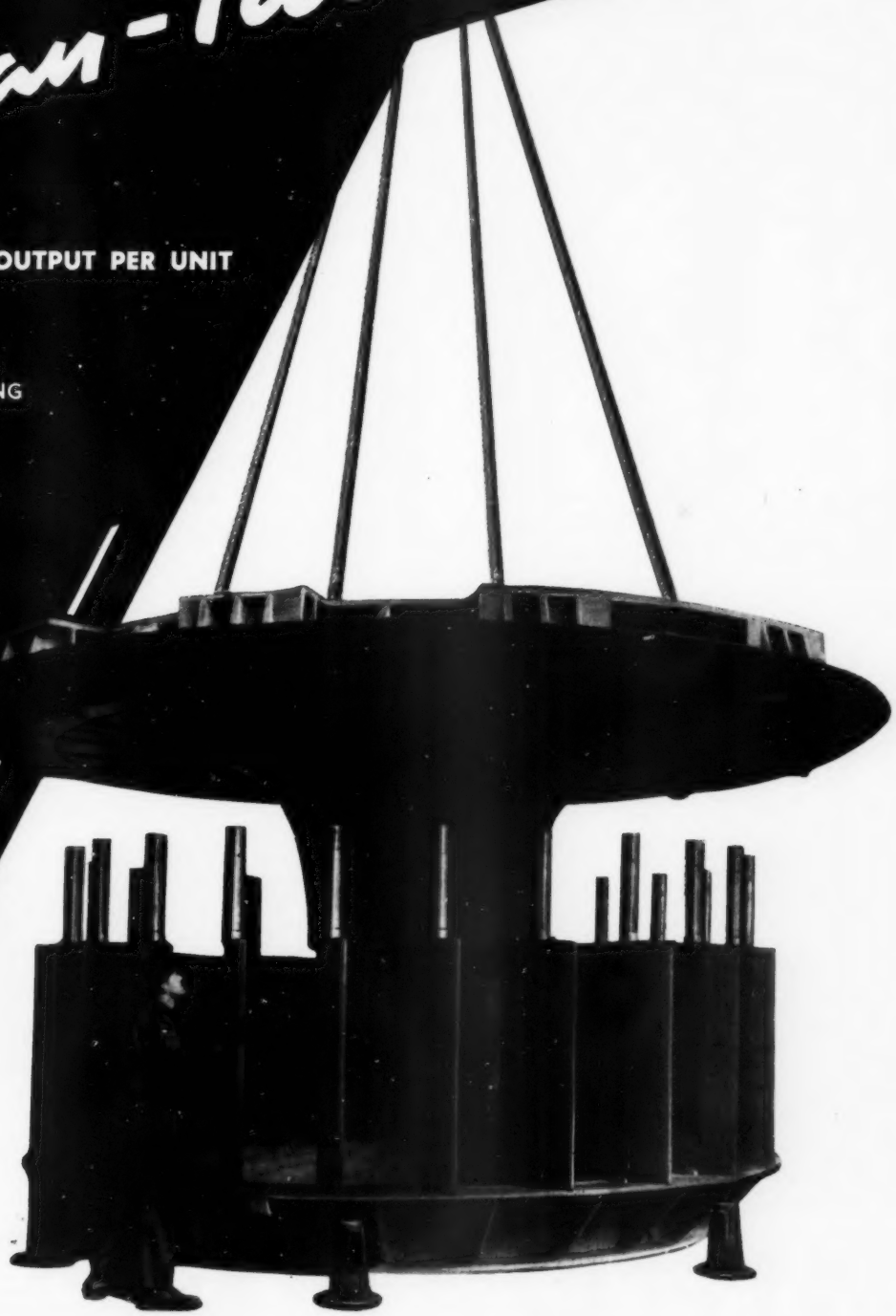
FOR TURBINES INCLUDING
DOUBLE REGULATION

EQUIPMENTS
FOR AUTOMATIC
OPERATION



**KAPLAN TURBINE FOR AN OUTPUT OF
11,000 HP DURING WORKSHOP ASSEMBLY**

TU 669

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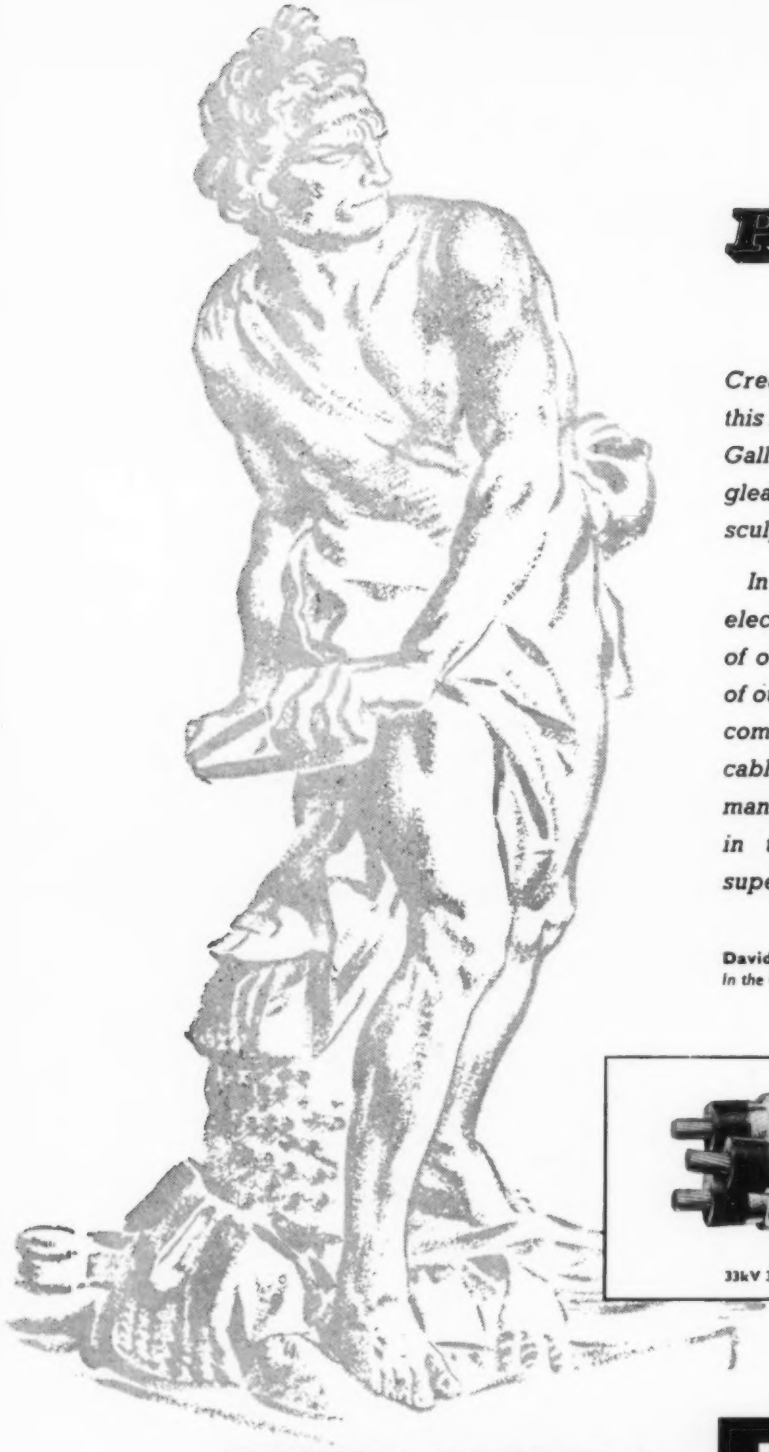
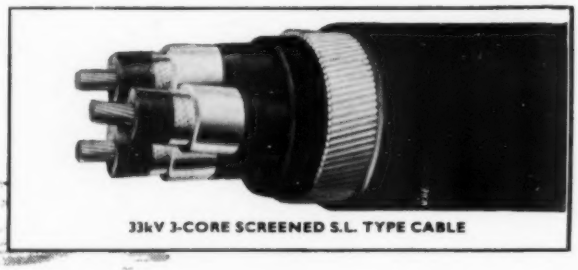


POWER

Created by Bernini in the 17th century, this lithe sculpture of David stands in the Galleria della Villa Borghese, Rome, a gleaming tribute in bronze to the sculptor's conception of power.

In our modern world, power — electrical power—is the great motivator of our industries, the light and warmth of our homes. And wherever electricity comes from, wherever it goes, Henley cables carry it surely and safely. No manufacturer has more experience in the design and manufacture of supertension cables up to 132 kV.

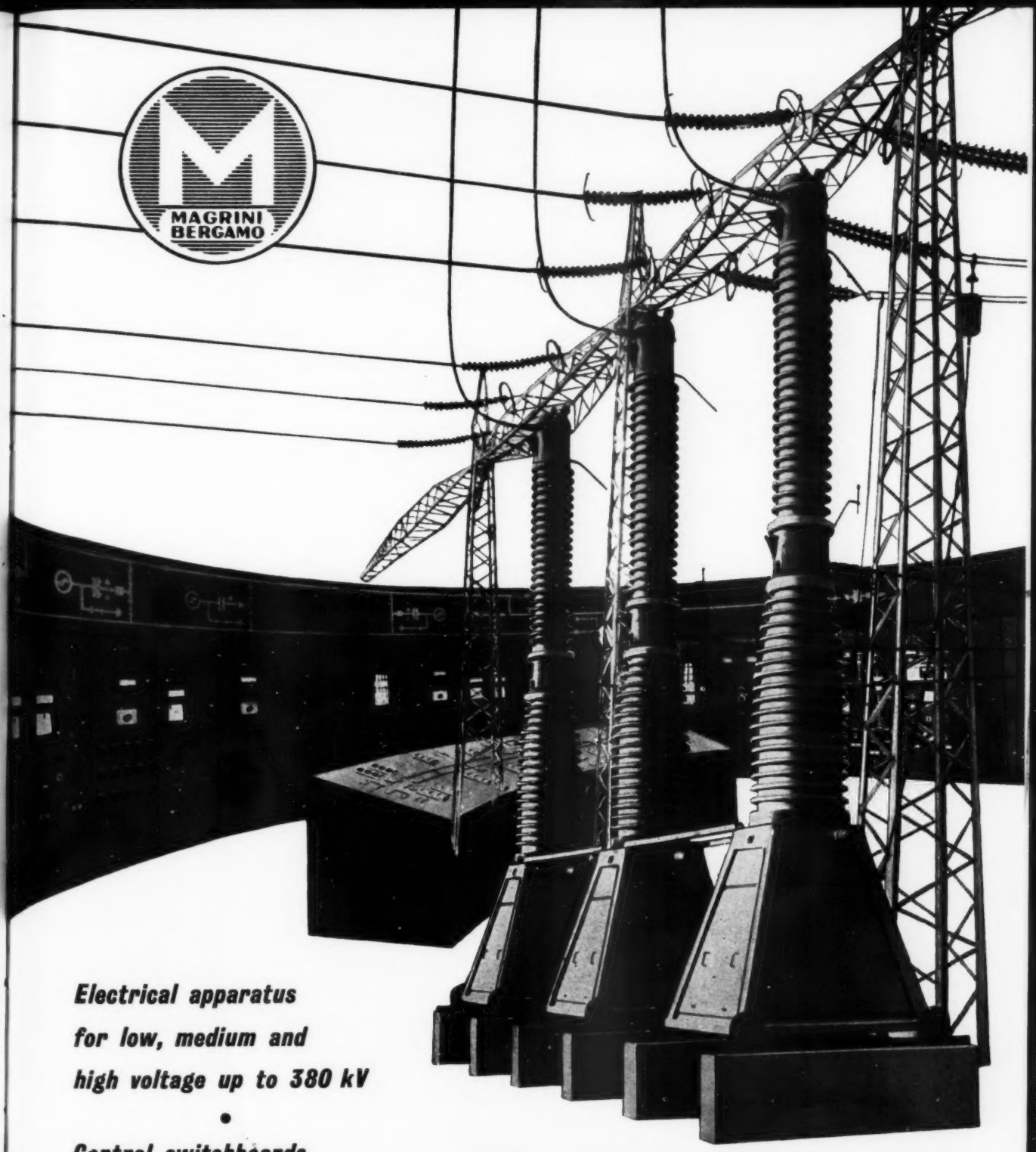
David, *by Bernini.*
In the Galleria della Villa Borghese, Rome.



33kV 3-CORE SCREENED S.L. TYPE CABLE

POWER CABLES by HENLEY

W. T. HENLEY'S TELEGRAPH WORKS CO. LTD · 51-53 HATTON GARDEN · LONDON E.C.1 · Tel: CHAncery 6822



Electrical apparatus for low, medium and high voltage up to 380 kV

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Control switchboards and control desks

•

Indoor and outdoor metal clad switchgear

•

Lightning arresters

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. . . the name of Horseley has been associated with major British engineering achievements.
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The Horseley Group offers a wealth of experience, and extensive facilities to meet the most exacting demands of Constructional, Chemical, Civil, Gas and Water Engineering.
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Also at
LONDON • SHEFFIELD
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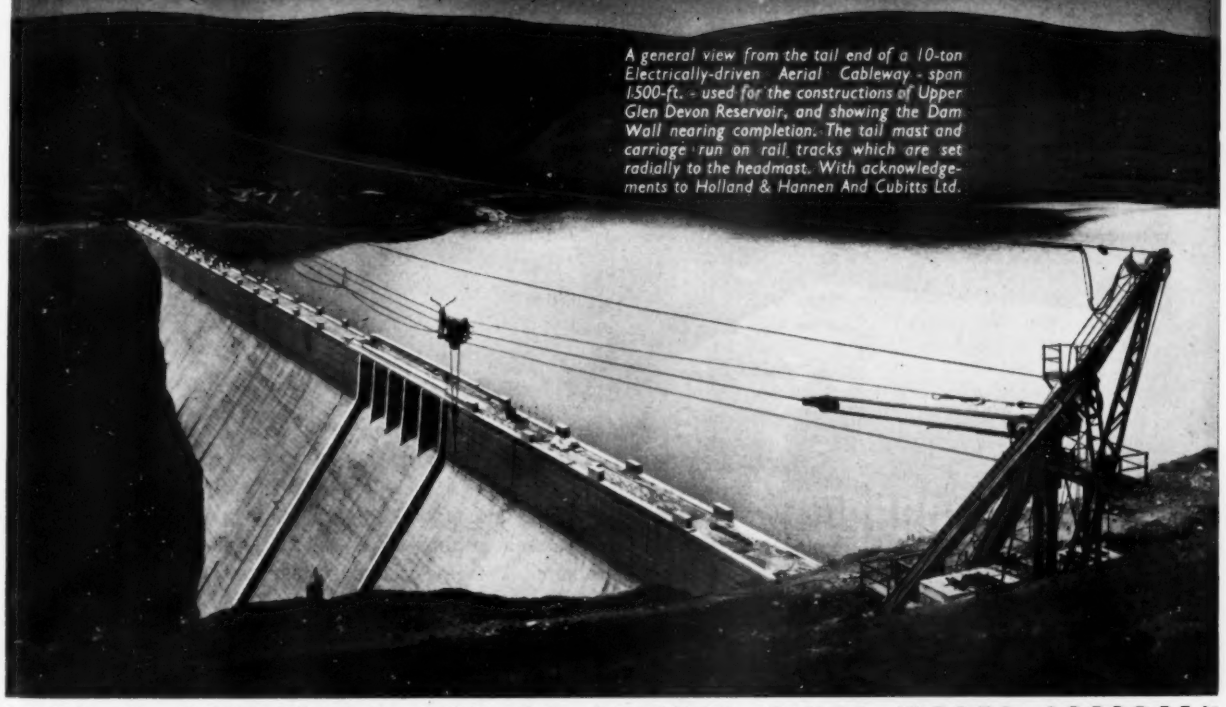
well on top of schedule

MOVEMENT of materials . . . . . that's the secret of meeting schedules on great projects. Getting the stuff in, putting the machinery on the job, - half the battle is won when movement is unhampered, when the equipment which handles the gear does so with unfailing reliability.

Henderson Cableways fit the description. Not only is each component built to the highest degree of engineering skill - Henderson Cableways are undoubtedly the most economical method of moving big loads on the majority of dam, barrage, bridge or viaduct contracts. Confirmation of this fact lies in the considerable number of cableways we have installed at vast projects throughout the world.

Henderson *CABLEWAYS*

lifelines to movement



A general view from the tail end of a 10-ton Electrically-driven Aerial Cableway - span 1,500-ft. - used for the constructions of Upper Glen Devon Reservoir, and showing the Dam Wall nearing completion. The tail mast and carriage run on rail tracks which are set radially to the headmast. With acknowledgements to Holland & Hannen And Cubitts Ltd.

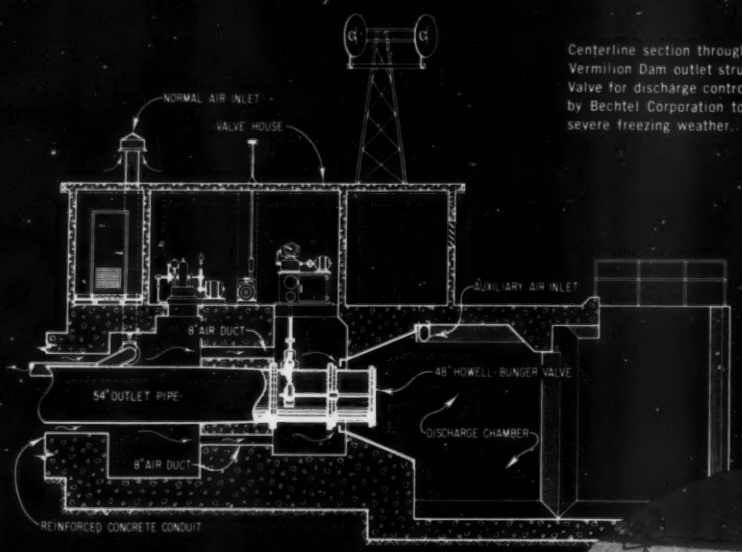
JOHN M HENDERSON AND CO LIMITED KINGS WORKS ABERDEEN

Hydro-Electric Power Station Equipment

Sécheron

Generators and motors with capacities above 150 kW. Single-phase and three-phase transformers for all outputs and voltages. Electrical applications in the field of traction. Installations of pumpless mercury arc rectifiers with rare gas filling. High-speed automatic regulators applied to various control problems. Welding rods and electric arc welding sets.

S.A. des Ateliers de Sécheron, Geneva



Centerline section through Southern California Edison Company's Vermilion Dam outlet structure shows 48-inch SMS Howell-Bunger Valve for discharge control. It is mounted in a chamber designed by Bechtel Corporation to minimize spray, erosion, and icing in severe freezing weather.

Valve discharging approximately 800 cfs at full gate has caused no noticeable erosion to channel in three years operation. Southern California Edison Company's Vermilion Dam and reservoir is on Mono Creek in the Sierra Nevada of California. At the Company's Portal Powerhouse on Huntington Lake, Calif., a 90-inch SMS Howell-Bunger Valve also operates under severe winter conditions by remote control.

Remote Controlled SMS Howell-Bunger Valve at Vermilion Dam Provides ***EASY REGULATION OF FREE DISCHARGE***

A 48-inch SMS Howell-Bunger Valve was chosen for Vermilion Dam to provide close, accurate regulation of releases from 10 cfs to 700 cfs. Remote control was necessary because of the isolated location of the site, and dependable operation and minimum maintenance were required, even in 20° below zero winter weather. Since late in 1954, this Howell-Bunger Valve has operated successfully under all conditions.

Rugged, simply designed and low in initial cost, the SMS Howell-Bunger Valve gives you:

- Free discharge with safe energy dissipation.
- Hydraulic balance without vibration.
- High coefficient of discharge for an energy dissipating valve.
- Minimum cavitation and maintenance.
- Simplicity of operation.
- Only one moving part in contact with stream.
- Discharge into atmosphere or under submerged conditions.

To obtain complete information, write to S. Morgan Smith Company, York, Pennsylvania.

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ANOTHER MAJOR FOUNDATION PROBLEM

SOLVED BY INTERNATIONAL ENGINEERING . . .

An important railroad trestle crossing, stretching 13 miles across America's Great Salt Lake, presented many problems.

Was the timber trestle construction efficient enough to afford minimum maintenance and permit full-speed train operation?

Would the sediments in the lake bottom support a rock fill embankment?

The International Engineering Company was called on for the answers. By extensive field and laboratory soil investigations, seismic refraction surveys, and feasibility studies, they established that rock fill construction had significant advantages over rehabilitation of the existing timber trestle. Later they developed the rock fill design . . . prepared construction plans and specifications and provided cost estimates.

Result: another complex project successfully launched by International Engineering!

SERVING DESIGN & ENGINEERING NEEDS WORLDWIDE WITH

- Reconnaissance and Surveys
- Preliminary Analyses and Evaluation
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- Design Drawings and Construction Specifications
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A subsidiary of Morrison-Knudsen Company, Inc.

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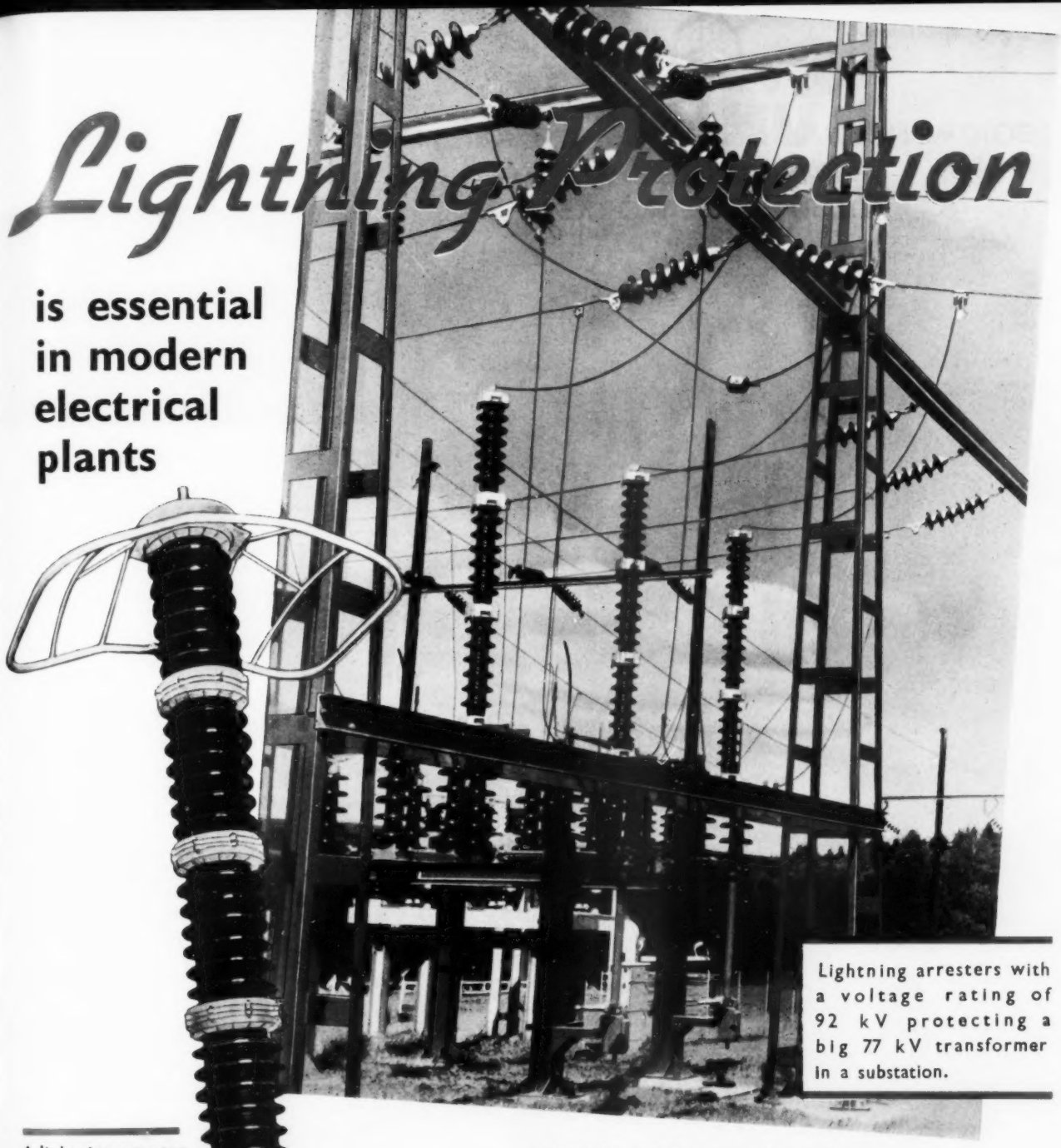
Lightning Protection

is essential in modern electrical plants



Lightning arresters with a voltage rating of 92 kV protecting a big 77 kV transformer in a substation.

A lightning arrester with a voltage rating of 400 kV. This type is installed in all stations in the Swedish 380 kV network.

ASEA's Lightning Arresters

cover the range 500–400,000 V and are manufactured in three different series according to their current rating: a heavy duty and a standard series tested according to the American Standards AIEE 28 A 1950 for Station Arresters (10,000 A) and a light series tested acc. to the same Standards for Line and Distribution Arresters (5,000 A).

Outstanding features:

Low spark-over level at high impulse steepness.
Low discharge voltage.
Precision in manufacture: discharge voltage guaranteed to ± 5 per cent.
Perfect sealing.
Built as a self-supporting column up to the highest ratings, with consequent low installation costs.

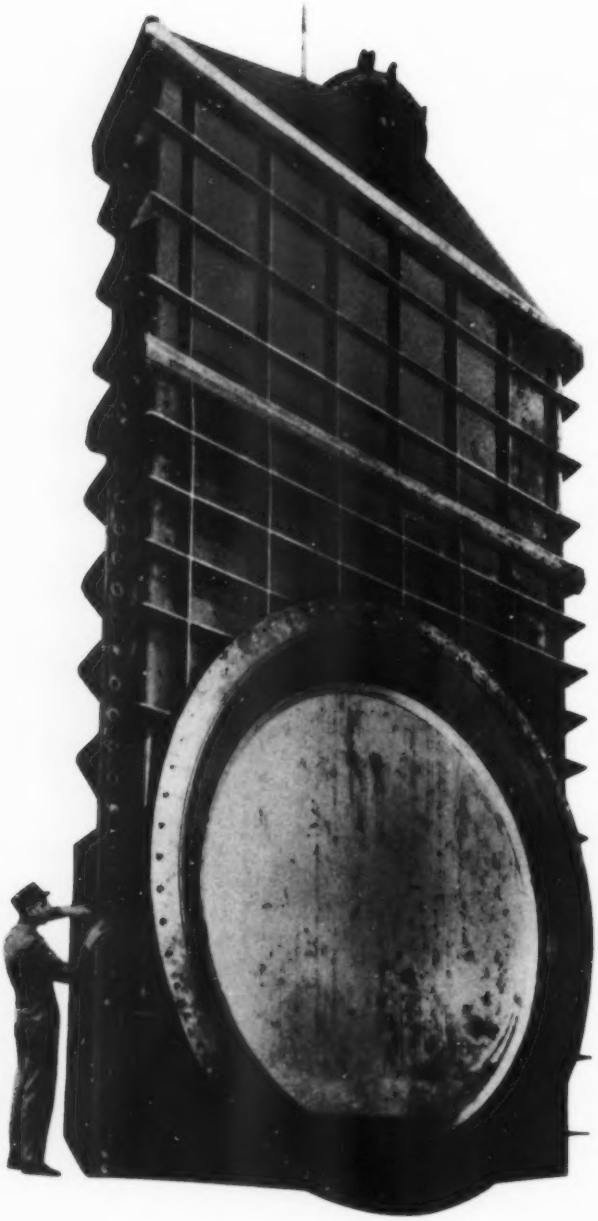
It is cheaper in the long run to install ASEA's efficient lightning arresters and avoid expensive repairs and service interruptions due to damaged equipment and blown high voltage fuses.

For all your lightning protection problems —consult

Västerås **ASEA** Sweden

DORTMUNDER **UNION** BRÜCKENBAU-
AKTIENGESELLSCHAFT
DORTMUND WORKS

For the Bhakra-Dam
the Joint Venture
Dortmunder UNION – M. A. N.
supplied
16 Jet Flow Gates and
2 Emergency Gates



View of a pre-assembled
96 inch. dia. Jet Flow Gate

Water Head:
265′ and 365′ resp.

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Works at Dortmund and Gelsenkirchen — West Germany

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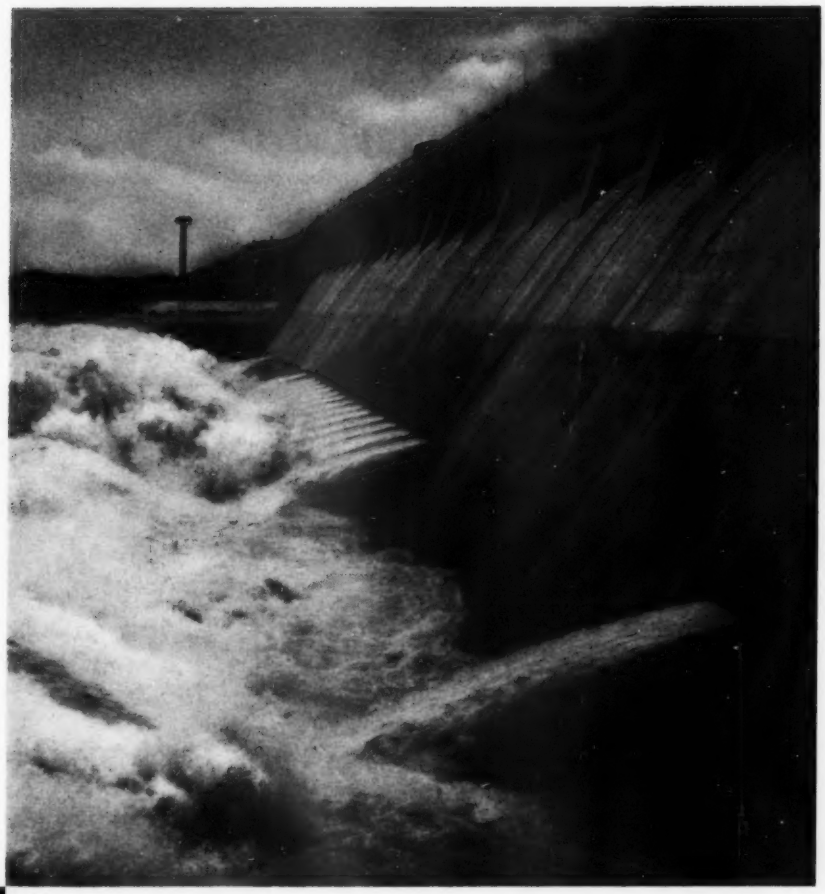

Part view of
Hirakud Dam
with some Deep Sluice
Gates opened
Water Head: 120'

For the Hirakud-Dam
the Joint Venture
M.A.N. – Dortmünder UNION
supplied and erected
64 Deep Sluice Gates

MASCHINENFABRIK AUGSBURG-NÜRNBERG AG.

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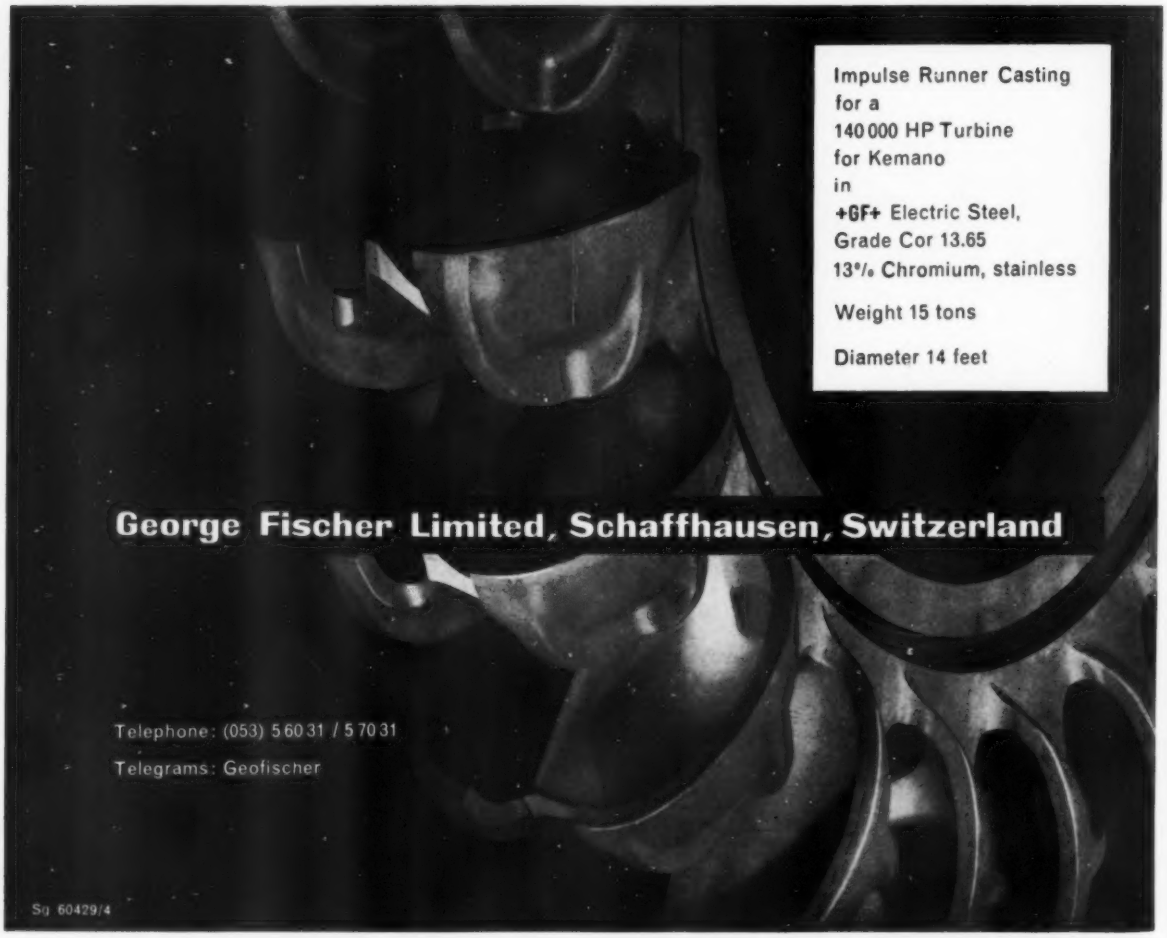

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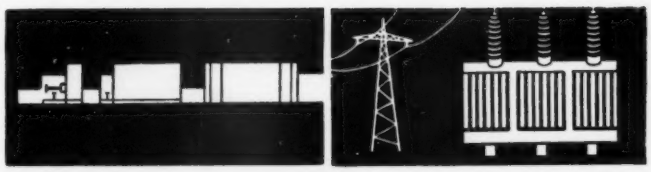

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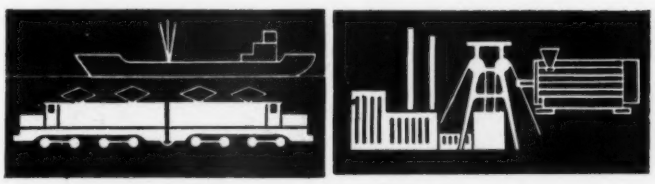

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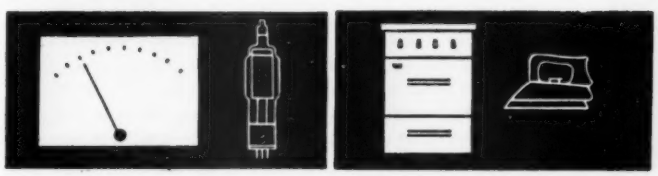

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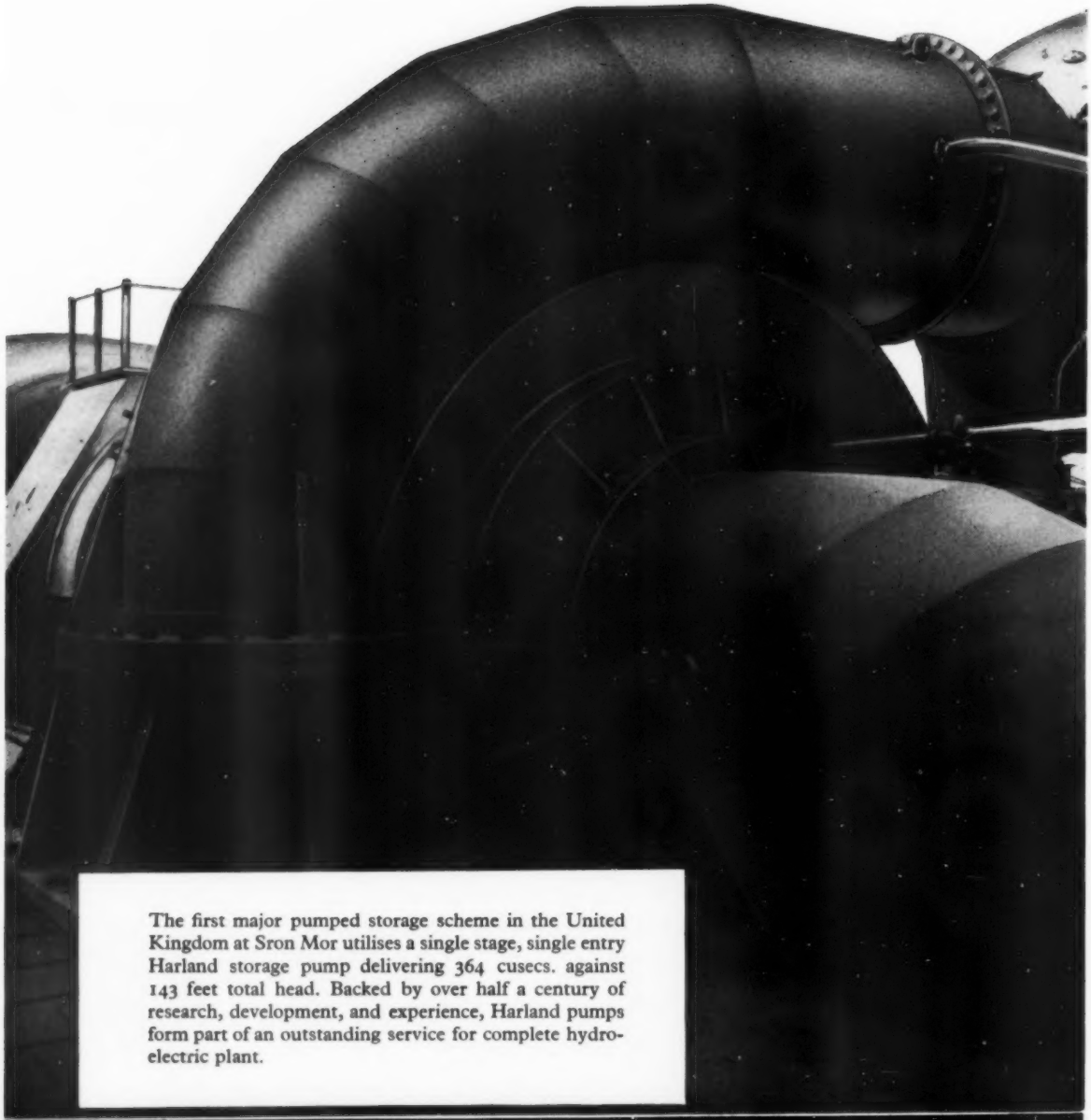

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WATER POWER

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Hydro-Electric Engineering Practice

IN the course of a luncheon held at the Savoy Hotel, London, to inaugurate a three volume compendium* bearing the above title, the general editor, Mr. J. Guthrie Brown, M.I.C.E., P.P.I.Struct.E., Partner of Sir Alexander Gibb & Partners, stated that not only was the use of water for the generation of power booming in all parts of the world at the present time but the advent of nuclear energy might very well increase the demand for hydro-electric stations.

In considering the world-wide development in hydro-electric engineering in the postwar years he drew attention to the important work being done by the North of Scotland Hydro-Electric Board. Since 1943, when the Board was established, it had spent over £180 million in the generation, transmission and distribution of electricity, and the new plant installed to date amounted to approximately 750 MW. This scale was modest in relation to other countries but it had changed the whole outlook in the Highlands.

In Africa, he continued, the final stage of development at Owen Falls had already practically been reached with 150 MW of installed plant. In view of this, further consideration was being given to additional developments down the Nile; one at present being investigated had a potential of 180 MW of plant and others would certainly follow as Uganda continued to expand.

At Kariba, in Rhodesia, some 1,200 MW of plant would be installed, and quite nearby, at Kafue, there was a further potential of 800 MW awaiting development. One of the largest schemes in the world was at Inga, in the Belgian Congo. This scheme had the gigantic potential of 20,000 MW and had an output of no less than three times the annual power production of Great Britain. There was also the Volta scheme in West Africa with a potential of 700 MW. He also referred to the High Dam at Aswan, which, while primarily an irrigation project, would have provision for no less than 2,000 MW of generating capacity.

Referring to the British Mission of Engineers which visited Russia during 1956, Mr. Brown stated that at the present time the Russians had in hand hydro-electric developments on the Volga alone totalling over 20,000 MW. This programme provided for two of the world's largest hydro-electric stations, one at Stalingrad with 2,300 MW and another at Kuibyshev with 2,100 MW of plant. A new station in Siberia would have a capacity of no less than 3,600 MW, and would be the largest in the world to date. East of the Urals the power potential was about four times that of European Russia. By 1960, the power production in Russia would be about three times that of Great Britain.

Continuing his survey, he spoke of other countries where major hydro-electric developments were in progress—Canada, Australia, New Zealand, the United States, India and China.

But what, he asked, would be the position in the future when the nuclear age was established? Some thought that with the advent of nuclear power the days of hydro-electric generation were over, but in his opinion the exact contrary was the case. One or two pointers to this, he thought, could be clearly seen already. A nuclear power station was best operated on a steady continuous base load for 24 hours of the day. To deal with the peak loads, the ideal arrangement would be to have conventional hydro-electric or pumped-storage stations which could be rapidly switched on, or off, as the load varied. In Britain, the first pumped-storage station to cope with the varying kilowatt demand was being constructed for the Central Electricity Generating Board at Ffestiniog in North Wales, with an installed capacity of 300 MW. The North of Scotland Hydro-Electric Board also had under consideration a pumped-storage scheme of the same size near Oban, and further and even larger schemes were contemplated in the future. An extensive series of these schemes could readily be visualised where there were suitable sites at which water at a low level could be pumped to a high-level reservoir by means of the surplus energy generated at night

* Reviewed on page 111 of this issue.

and off-peak periods by the chain of nuclear stations to be built in the near future. With regard to their size, Mr. Guthrie Brown thought there was no reason why stations having a capacity of 1,000 MW or more should not be constructed.

He thus concluded that far from hydro-electric engineering reaching its termination, a new age was dawning for it. As was well known, once the capital costs of a hydro-electric installation had been written off by sinking fund payments over a period of years, there was no other form of energy at present, or in the foreseeable future, which could generate electricity as cheaply as water power. As an example of this he cited the small installation at Foyers, near Inverness. This scheme, the oldest in Britain, was constructed in 1896, or fully 60 years ago. Not only were the original pipelines, power station, turbines and generators still in existance and producing electricity but they had kept on doing so for 60 years with a minimum maintenance and repair work. With the capital charges long since written off, the cost of production of electricity under these conditions was infinitesimal.

The Nyasa-Shire Complex

AN important paper on the hydrology of Lake Nyasa and the River Shire was presented in January to the Institution of Civil Engineers by Mr. N. J. Cochrane. Lake Nyasa is the third largest lake in Africa, and with its outflow, the Shire, is subject to a delicate hydrological balance. In addition to seasonal fluctuations in lake level averaging 3 to 4 ft. there is a long-term variation of upwards of 18 ft. In consequence, there was no appreciable outflow from the lake between 1915 and 1937, during which period the outlet became blocked. In 1937 this blockage was overtopped and scoured away, and the Lower Shire valley was largely flooded. Of the total rainfall, 94–95% is evaporated or transpired, leaving only 5–6% of free water, and Mr. Cochrane was able to show that a small variation in rainfall produces a large variation in free water.

A particularly interesting section of the paper discussed the relationship between free water and sunspots. Mr. Cochrane concluded that the significant factor was not the presence or absence of sunspots but their rate of change, and he produced curves which seemed to indicate clearly that there is at least a qualitative relationship between the rate of change of sunspots and the amount of free water available. This correlation was also shown to extend over many decades to the free water on Lake Victoria and to the mean temperature in central England. Slides were shown to demonstrate the same correlation in respect of flow in the Severn, mean temperature at Berlin, and cloudiness at Oxford. In addition, the author presented the outcome of an accurate prediction of the behaviour of Lake Nyasa in 1957, though he said the method was not really as effective as the resulting error of $\frac{1}{2}$ in. would suggest.

When discussing evaporation, Mr. Cochrane quoted the empirical formula which he first published in the May 1956 issue of WATER POWER, and which he believes is capable of giving the annual evaporation from a lake or reservoir within $\pm$ 10%. In his paper he included a table showing a remarkably close agreement between the measured and calculated values for six lakes and reservoirs, and presented the results of water budgets he has carried out on Lake Nyasa revealing a similarly close agreement between calculated and measured evaporations.

The regulation of the lake and river, as the author pointed out, is an intractable problem, but Mr. Cochrane tentatively suggested a minimum outflow of 5,000 cusecs, which would require a variation in lake level of at least 7 ft. and probably 14 ft. at long intervals. To obtain this flow by clearing the outlet channel would involve an enormous excavation programme, and an alternative would be to install a low-head pumping station. A third possibility would be to raise the lake level to about 6 ft. above the 1937 flood level, in which case neither dredging nor pumping would be necessary.

Sir Thomas Fry, in the subsequent discussion, suggested that the pumping station method would be more advantageous, and in reply Mr. Cochrane agreed that the use of the enormous volume of water stored as a wasting asset, as for example coal or iron ore, represented a tremendous source of wealth.

A report on the Shire Valley, prepared by Sir William Halcrow and Partners, was published by the Government of Nyasaland in 1955, and an article on this report appeared in our September 1955 issue.

Australian Rainmaking Tests

ACCORDING to the Minister-in-Charge of the Scientific and Industrial Research Organisation, Mr. Casey, Australian scientists are close to finding out whether it is possible to modify the weather by producing enough rain artificially. Mr. Casey said that Australia's rainmaking experiments should reach finality within the next year or, at the most, two years, and during the next twelve months, experiments would be extended greatly. He added that Australia's experiments were ahead of anything else in the world, and overseas scientists were now looking to Australia for information.

Hungarian Electrical Development

THE production of turbo and hydro generators and other heavy electrical goods is to be expanded under a £12 million development plan announced by the Ministry of Foundries and Heavy Industries. The plan covers 1958–60. This sum will be spent on modernising and reconstructing factories producing heavy electrical goods, including the Klement Gottwald Factory. The plan aims at a 27% increase in production next year and a 56% rise by 1960. Production of turbo and hydro generators is expected to increase by nearly 80% during the three years.

Beaumont Rapids, Canada

THE Shawinigan Water & Power Company is making good progress with Beaumont Rapids plant, which is designed to develop 240,000 kW on the St. Maurice river. There will be six Francis-type turbines, each rated at 55,000 h.p., vertically coupled to 45,000 kVA, 13,000 V, 60 cycle generators. A maximum head of 125 ft. will be made available by the impounding dam which will have a crest length of 1,600 ft. and will

accommodate the intakes to the semi-outdoor type power station, a flood-water spillway section, the necessary sluices to regulate the water level, and a log chute. This project is estimated to cost $56·5 million and is being designed and constructed by The Shawinigan Engineering Co. Ltd.

Tunnelling at Stornorrfors

ON several occasions we have referred to the Swedish State Power Board's 375 MW development at Stornorrfors on the Ume; it is noteworthy on two counts, as it will be Sweden's largest hydro-electric station and will include the world's largest water tunnel. This tunnel, which forms the tailrace, is 87 ft. high by 48 ft. wide, and is 13,000 ft. long. Initially a pilot tunnel was cut for the whole length along the top of the section, 22 drillers working on three levels on a drilling platform. In each cut 175 holes, 23 to 30 ft. long, were charged with 2,000 lb. of explosive and fired on a millisecond delay system, and with each blast 39,000 cu. ft. of rock was broken, Marion and Ruston-Bucyrus electric shovels loading it into Euclids for transport to daylight. After the completion of the pilot tunnel the excavation was enlarged in two further stages to the final height.

The supply tunnel is 7,900 ft. long, and the three penstock shafts are 28 ft. in diameter and 244 ft. deep. In addition to the tunnels the excavation includes the machine hall and draft tubes, a transformer hall, and a surge chamber.

In spite of this heavy excavation programme, the overall cost per kW installed will be only £39.

Work started on Benmore

CONSTRUCTION has started of the Benmore hydro-electric station on the Waitaki River, South Island, New Zealand. A mechanical shovel working at the edge of the Waitaki river represents a modest but significant start on a station that will have a capacity of 480 MW and will be New Zealand's largest. The solitary shovel has begun to strip the crust of weathered rock from the line that will be followed by blasting teams as they cut the diversion channel for the river to follow while the dam is being built. A Ministry of Works officer said recently that blasting of the diversion cut out of solid rock would not begin until March. It would be possible to divert the river through the cut in about 18 months' time. Similar to the cut at the completed 320 MW Roxburgh project, the channel would be 50 ft. deep and 860 yards long. From it would come 333,000 cu. yards of mainly solid rock, much of which would go into the toe of the earth dam.

Explosives and Automation

AS large consumers of explosives, contractors on hydro-electric schemes may be intrigued to learn that "automation" has now impinged upon explosives manufacture. Automation is now the regime at the Ardeer, Ayrshire, factory of the Nobel Division of Imperial Chemical Industries. A few years ago a new nitro-glycerine plant was erected, operated by semi-remote control, but it was stated by I.C.I. at the time that eventually it would be operated by completely remote control. This important stage was accomplished at the end of August 1957. The control desk has been removed to a concrete building at some distance from the nitrating room. Two television cameras installed in the nitrating room can "observe" the process vessels through a long window. The image is relayed by closed circuit to the remote control room, where it is reproduced on television screens on the instrument panel, while microphones can transmit the sounds of the operation. This nitro-glycerine plant operates on the Biazzi system, but the instrumentation was worked out by collaboration between a Nobel Division team and the Biazzi Company.

Kariba and the Copperbelt

AT a recent informal meeting of Rhodesian Selection Trust Limited and Roan Antelope Copper Mines Limited, Sir Ronald Prain spoke appreciatively of the progress being made at Kariba. He pointed out that the plans of his companies for obtaining power depended on the successful completion of the Kariba scheme within the scheduled time, which was 1960, and it was satisfactory to be able to report that the work appeared to be well up to schedule. A most important phase in construction had been reached in November when the main cofferdam was pumped dry. This had concluded what was considered to be the most difficult and dangerous phase of the whole operation, and left the way clear for the construction of the main dam wall.

He also complimented their neighbours in the Belgian Congo on their successful achievements in their hydro-electric schemes on the Lualaba river and in their timely assistance in supplying 50% more power than specified in the original contract.

Remote-Control Equipment for Kariba

A CONTRACT for the manufacture and installation of remote-control equipment for the Kariba hydro-electric scheme has been awarded to Standard Telephones and Cables Limited of London. It is one of the biggest orders of its kind ever placed in Great Britain. The equipment to be installed will give the Kariba engineers finger-tip control of the system which will link Kariba with the existing thermal stations in the Central African Federation. The contract, which has been awarded by the Federal Power Board of Rhodesia and Nyasaland, includes direct-wire control equipment at the main Kariba power stations, as well as at a number of substations.

S.T.C. remote-control equipment was also provided for another large-scale African project, the Owen Falls hydro-electric power scheme in Uganda.

Testing Kariba Generators

IN the first part of the article on Kariba, on page 10 of our January issue, it was stated that it would not be possible to erect and test the generators fully in the manufacturers' works. When the original project report was drawn up it was considered unlikely that the machines, owing to their size, could be so tested, but the successful tenderers, Metropolitan-Vickers Electrical Co. Ltd., unlike many of their competitors, do in fact possess the necessary facilities, and the first generator will be fully tested in their works.

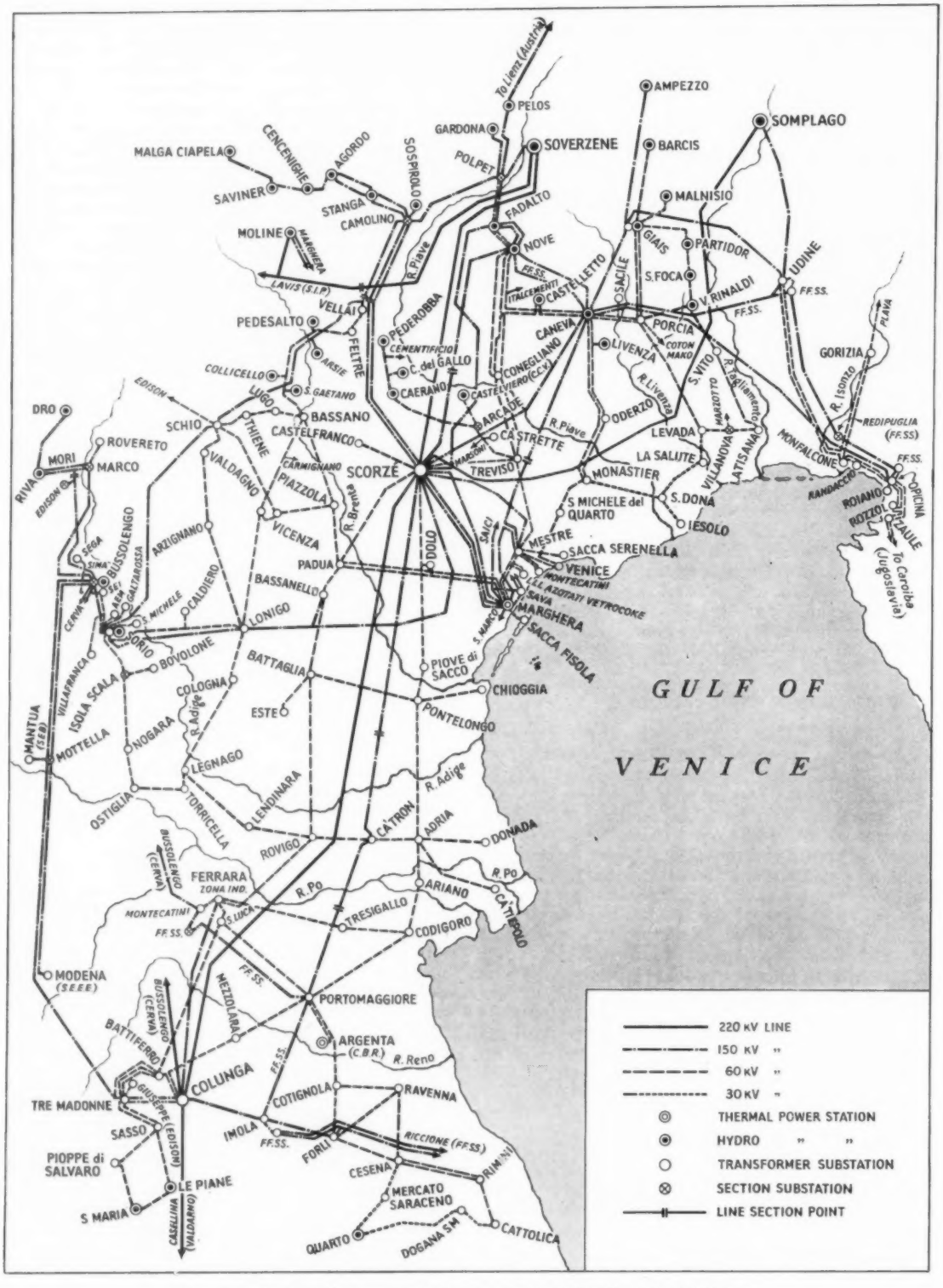


Fig. 1. The electrical transmission network of the Società Adriatica di Elettricità. This drawing, which is diagrammatic and not to scale, also shows the principal rivers from which power is derived

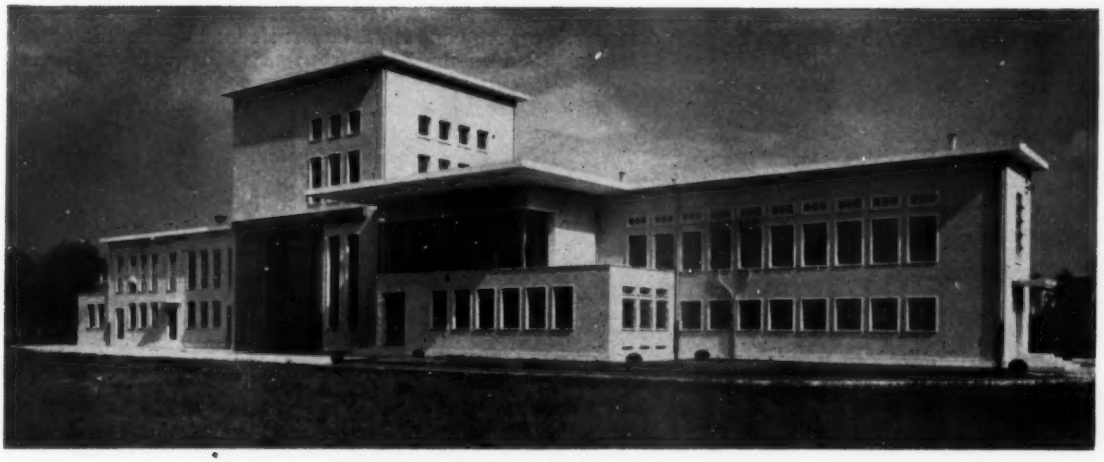


Fig. 2. Exterior of Scorzé substation building

Some SADE Developments

We commence a series of articles describing some recent hydro-electric developments carried out by Società Adriatica di Elettricità (SADE). The present article gives a general outline of the Company's activities and principles and programme of development, and describes the electrical network with special reference to the substation and circuit-breaker test station at Scorzé

PART ONE

THREE years ago Società Adriatica di Elettricità (SADE) celebrated its jubilee, for it was constituted in Venice in January 1905 under the inspiration of Giuseppe Volpi. From modest beginnings, and in spite of the setbacks and physical damage sustained during the two world wars, the Company has made such progress that its territory now extends from Trieste in the east to Verona in the west, and from Bologna in the south to Cortina in the north. By 1955, its jubilee year, the Company's installed hydro-electric capacity had reached about 1,000 MW, capable of an average annual production of 4 milliard kWh. Thermal capacity of 230 MW was also in service, representing 1 milliard kWh annually, and the main transmission system, at voltages ranging from 30 to 220 kV, involved 4,000 km. of transmission lines and two million kVA of transformers.

A chart of the electrical transmission system is given in Fig. 1, and on this chart are indicated, although not to scale, the main watercourses utilised. By far the greatest proportion of the power is derived from the rivers which flow generally south and south-east from the Eastern Alps and the Dolomites into the Adriatic. Reading from west to east these include the Adige, Brenta, Cordevole, Piave, Cellina and Tagliamento. Isolated developments are to be found on the Savio and Brasimone to the south, the Ponale, which flows into the northern extremity of Lake Garda, to the west of the Company's territory, and the Isonzo in Yugoslavia.

To balance up the hydro generation a steam station is in service at Marghera near Mestre. This station had an initial capacity of 30 MW, but it has been progressively extended to its present capacity of 230 MW.

Principles of development

Important new developments have just been completed, are now in process of execution, or are projected, on the Cordevole, Piave, Cellina, and Tagliamento, and we hope to give some account of the situation on each of these four watercourses in subsequent articles. By way of preface, however, we may refer very briefly to certain design principles on which the developments have been based.

A tendency that is to be found in the more recent developments is to concentrate the production of a watercourse, or of a major section of it, in a single large power station served by a comparatively small head reservoir, the main seasonal storage being loca-

ted considerably farther upstream. The local headpond is large enough to cope with all peak demands, and in consequence the tunnels between the seasonal reservoir and the head reservoir need to be proportioned only for the average flow. The station can therefore be placed to take advantage of the maximum head without calling for the large-diameter tunnels that would be necessary if it were fed direct from the seasonal reservoir. The station is normally constructed underground so that it can be located close to the headpond reservoir, enabling the size of the surge chamber to be kept to a minimum.

An outstanding example of this technique is to be found on the Piave. Soverzene, which is of 220 MW capacity and is the largest station at present in operation on the SADE system, is fed from Val Gallina reservoir, having a live storage of 5·8 million cu. m. The main storage, of 64·7 million cu. m., is held at Pieve di Cadore, 24 km. upstream, and an intermediate storage, of 150 million cu. m., is being constructed on the Vaiont 6 km. upstream from Val Gallina. The tunnel from Pieve di Cadore to Val Gallina has a diameter of only 4·5 m., Soverzene itself being served by two 5 m. diameter tunnels from Val Gallina.

Similar principles are being followed in the develop-

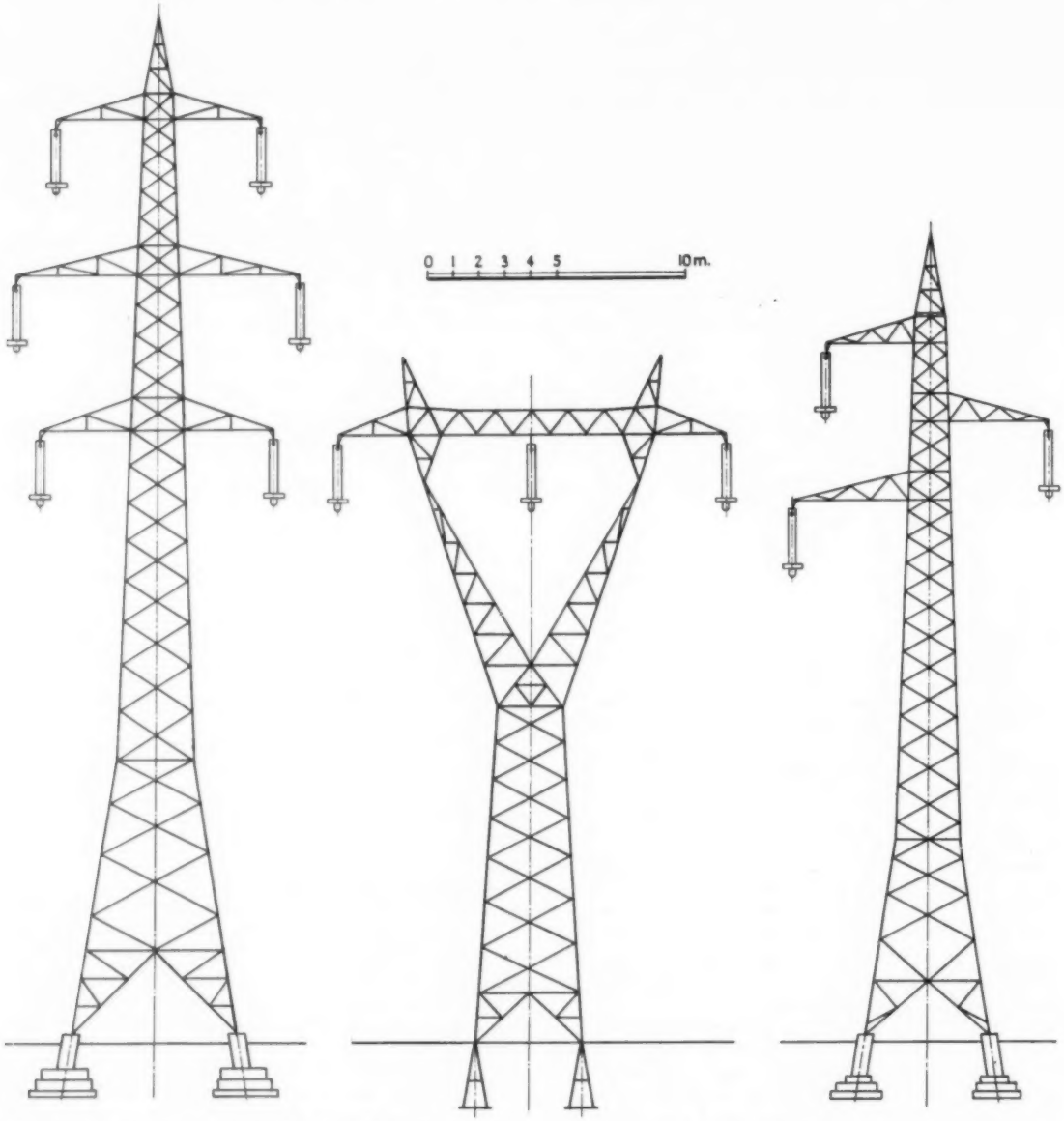


Fig. 3. Towers used on the 220 kV Soverzene-Scorzé-Colunga line: (left) double-circuit tower used for the first 5 km. from Soverzene; (centre) single-circuit tower used thereafter in the valley; (right) tower used in the plain

Fig. 4. View in Scorzé control room overlooking the outdoor substation

ment of the Tagliamento. The seasonal storage of 70 million cu. m. is held on the Lumiei, and in this instance is first utilised in Ampezzo station, of 60 MW capacity, 4 km. downstream. Some 31 km. below Lumiei, however, an underground station is being built at Somplago, which will have a capacity of 275 MW and will therefore be larger than Soverzene, weekly storage being held at Ambiesta 9 km. above Somplago.

In the field of dam design SADE has done much pioneer work.* The terrain is characterised by narrow, deep gorges in good-quality limestone, which has favoured the adoption of arch dams; indeed, within a radius of 80 km. centred on Pieve di Cadore the Company has built about 15 arch dams and about another ten are projected. Economic conditions in Italy, too, have influenced design, for the economic problem is the provision not of labour but of material. Thus, designs have been sought to make the most efficient use of concrete, even if they involve somewhat higher shuttering costs, and in consequence the thin double-curvature arch dam has been greatly favoured. Some excellent examples of this type have been built, such as Lumiei, Val Gallina and Maè and construction is now proceeding on the Vaiont dam, which will be 265·5 m. high, and, it is believed, will be the highest arch dam in the world. The height of this dam illustrates a further characteristic of the terrain—that the gorges are so deep and narrow that the dams have to be unusually high to impound an adequate volume of water.

In the arch dams built a few years ago (e.g. Lumiei) the design aimed at producing an exactly symmetrical structure—a feature that presents important advantages in the resulting even distribution of stress and in its inherently good resistance to sudden loading due to floods or earthquakes. Nevertheless, it is not always practicable to obtain exact symmetry; the valley profile may be so far from symmetrical that the necessary excavation would be uneconomic, and in any case the mechanical properties of the rocks on the two sides of the valley may differ. Thus, although symmetry is regarded as a desirable objective, even greater importance is attached to the principle of continuity, which consists in so modelling the dam profile, both horizontally and vertically, that the stresses between the various parts of the structure and between the structure and the rock are smoothly transmitted, distributed and absorbed. This principle of continuity is perhaps best appreciated from an examination of the photographs we hope to publish in subsequent articles—or better still, from an examination of the dams themselves. Indeed, their shapes convey a sense of harmony and of fitness for purpose which we found most satisfying.

In this connection use is almost invariably made of a peripheral joint, which separates the dam proper from its abutments and foundations. By this means it is often possible to make the dam itself symmetrical, leaving the abutments and foundations to take up any asymmetry; the main purpose of this joint, however, is to prevent local concentrations of stress in the adjacent areas of the dam wall, especially under the influence of temperature changes.

Another noteworthy feature of the SADE dams is the unusually comprehensive instrumentation built into the structures; thus a continuous record can be kept of the behaviour of a dam under all conditions of loading and temperature, enabling the actual performance to be compared with design predictions.

* For a much fuller discussion than is possible in the space at our disposal the reader is referred to "The Most Recent Dams by the SADE in the Eastern Alps," by Dott. Ing. Carlo Semenza, M.I.C.E., *Proc. I.C.E.*, Vol. 1, No. 5, September 1952, and abstracted in WATER POWER, May 1952, p. 164.

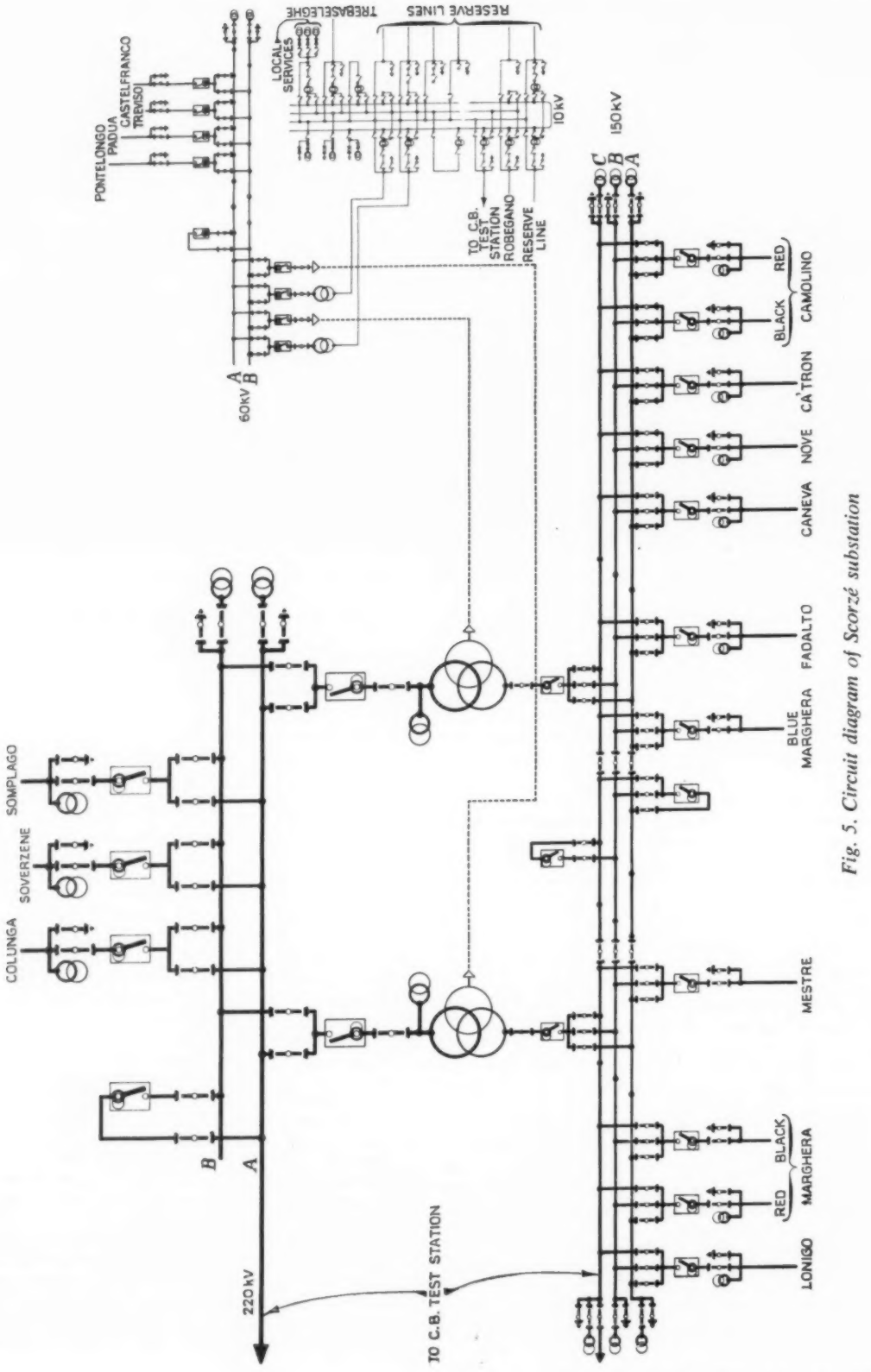


Fig. 5. Circuit diagram of Scorzé substation

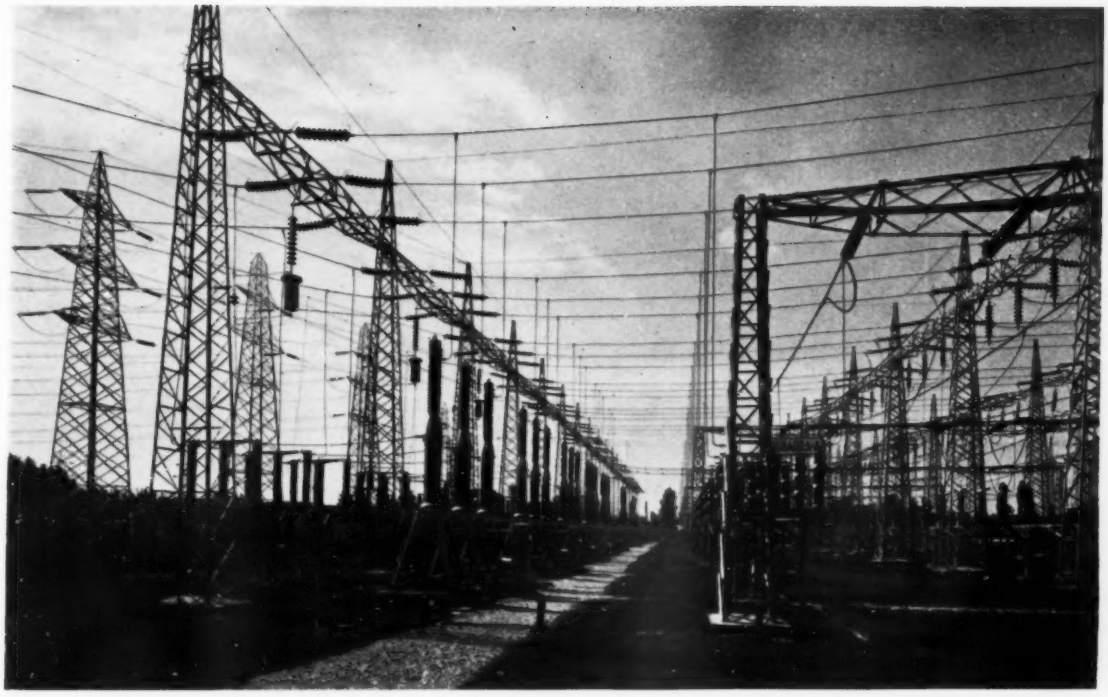


Fig. 6. Scorzé switchyard. The 150 kV gear is on the left

For example, the Pieve di Cadore dam contains about 800 instruments of various types for measuring deformations, temperatures and concrete humidity.

Electrical network

Seeing that, at this stage, we are sketching an overall picture of SADE developments, this may be a suitable point at which to describe the electrical network, and reference should again be made to Fig. 1.

The original transmission voltage adopted by SADE was 30 kV, but from 1916-19 the bulk of the system was converted to 60 kV. This 60 kV network has been steadily extended, but in 1926 the first 150 kV line was erected from S. Croce power station to Portomaggiore, a 150/60 kV substation being built at Portomaggiore. In 1952 the first 220 kV line was run from the new Soverzene station to Scorzé and Colunga.

Scorzé and Colunga substations form the nodal points of the system, Scorzé being roughly in the electrical centre of gravity and Colunga in the extreme south. All three systems—220, 150 and 60 kV — are interconnected therefrom; with the advent of the 220 kV trunk lines and the extension of those at 150 kV the tendency has been more and more to treat the 60 kV system as a distribution network on which high-voltage transmission at 220 and 150 kV has been superimposed. The system control and the load dispatching are exercised from Scorzé.

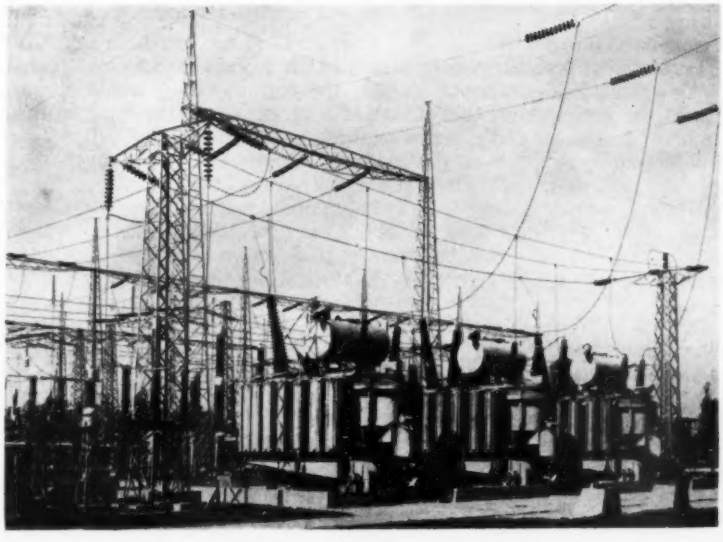


Fig. 7. Main transformer banks at Scorzé

A transmission voltage of 220 kV from Soverzene was adopted not only for the economical transfer of bulk power within the SADE territory but also to enable the system to be linked into the Italian 220 kV grid, and for this purpose interconnections have been made at two points. From Soverzene a 220 kV line is taken

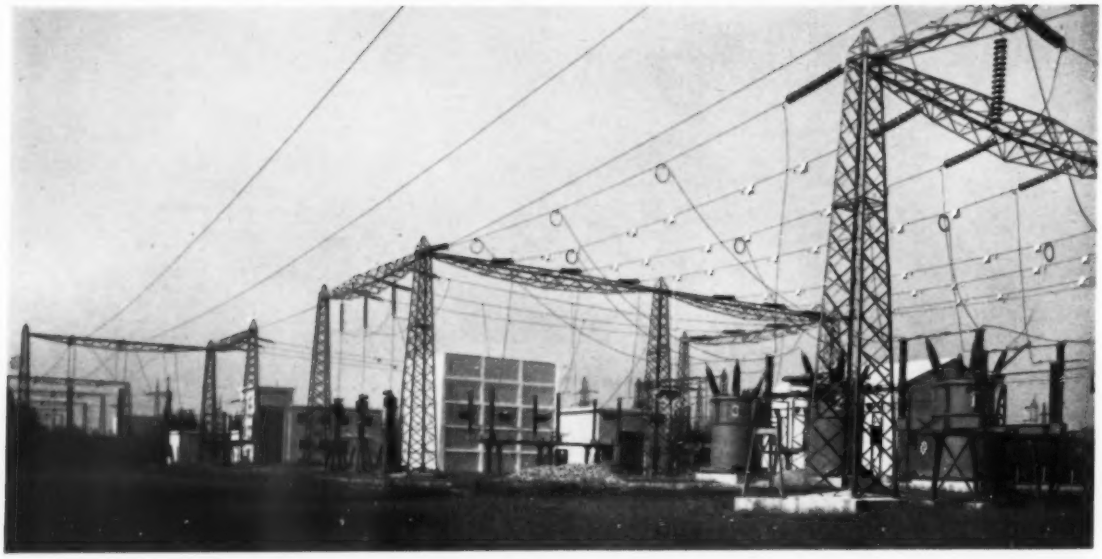


Fig. 8. General view of Scorzé circuit-breaker test station

direct to the Società Idroelettrica Piemonte's substation at Lavis, and from Colunga two lines go north-west to Bussolengo and Arsiè and two lines go to Casellina.

Fig. 3 shows in outline the three types of tower used on the Soverzene-Scorzé-Colunga line. This line, which runs almost directly from north to south, is 209 km. long, the first 36 km. of which is in mountainous country ranging up to an altitude of 750 m., and the remainder is in the north-Italian plain. For the first 5 km. from Soverzene the line is carried on the double-circuit tower outlined on the left of Fig. 3, after which this gives place to the Y-type single-circuit tower shown in the centre drawing. When the plain is reached, this tower in turn gives place to the pyramidal tower seen on the right.

The towers are of galvanised structural steel and carried on separate concrete footings except for the Y-type towers, the footings of which are grouted direct into the rock. The suspension strings consist of either 14 or 18 insulators, of 5,500 and 7,000 kg. critical load respectively, protected by guard rings at the bottom and horns at the top. The normal span between towers is 350 m., and the conductors consist of 30 aluminium and 19 steel wires, giving a section of 428·19 sq. mm. and an overall diameter of 26·9 mm. The breaking load is 14,200 kg. Compression-type joints are used. The guard wires are formed of 19 steel strands and have an overall diameter of 11·5 mm. and a breaking load of 9,350 kg.

Hitherto we have described how the 220 kV lines serve the SADE system and the Italian national grid, but we must now turn our attention to an important international link with Austria. This line runs from Pelos station in the upper reaches of the Piave valley to the OEWAG substation at Leinz, whence connection is made with the Reisseck-Kreuzeck scheme. Quite apart from its significance in the development of international exchanges of power, this line represents a noteworthy engineering achievement, for in the course of its 54 km. it traverses wild and difficult mountain country, culminating in the Cima Vallona pass, which crosses the frontier at an altitude of 2,425 m. In addition to having to withstand the weather hazards inseparable from such a route through the Dolomites, the line had to pass through one of the most heavily wooded regions in Italy.

The line is designed to operate ultimately at 220 kV but is working at present at 130 kV. It is arranged on Y-type single-circuit towers with three ACSR conductors horizontally in line, surmounted by two galvanised-steel guard wires. For design purposes the Italian side of the line, 21 km. long, is divided into two sections meeting at Rio Saletta. The section from Pelos to Rio Saletta is designed to withstand the following conditions: (a) an overload of 3 kg. per m. on the conductors and 2 kg. per m. on the guard wires at a temperature of 0°C; (b) an ice coating 12 mm. thick, with wind at 65 km. per hour at a temperature of −20°C; (c) wind at 130 km. per hour at −20°C. From Rio Saletta to Cima Vallona, which is the more exposed section, the corresponding conditions are: (a) an overload of 8 kg. per m. on the conductors and 5 kg. per m. on the guard wires at −5° C; (b) 5 kg. per m. on the conductors and 4 kg. per m. on the guard wires at −35°C; (c) wind at 150 km. per hour at −35°C. All the equipment has a factor of safety of at least 2·5 under the specified conditions.

Other international connections are provided to Yugoslavia. Within Italy many links with other electric Groups and FF.SS (Italian Railways) are in operation at 130 and 60 kV.

Scorzé substation

Scorzé and Colunga substations are virtually identical, and a description of Scorzé can be taken to cover Colunga also; we need only mention that at Colunga, which is so far from the main SADE power stations, two 30 MVA hydrogen-cooled outdoor rotating synchronous condensers are installed. Scorzé, however, is unique in that associated with it is a short-circuit test station where circuit breakers can be tested

under full system conditions direct from the grid. The value of such a facility in the development of circuit-breaker design needs no emphasis.

The circuit diagram for Scorzé is given in Fig. 5. The 220 kV lines from Soverzene and to Colunga are controlled by double busbars, provided with a bus-coupling circuit breaker; in addition the 220 kV line is in readiness to receive the energy from Somplago station.

On the 150 kV system there are no less than 11 incoming lines apart from transformer connections, and to secure the requisite flexibility of control it was decided to adopt a triple-busbar system, which, in addition, is sectionalised at two points, the bus-coupling circuit breakers being in the centre section.

The 60 kV lines, of which there are four, are again controlled by double busbars, and there is a 10 kV triple-busbar system (two main bars and one auxiliary) for local and auxiliary supplies.

Interconnection between the 220, 150 and 60 kV supplies is effected by six single-phase three-winding transformer units connected in star to form two 66/66/25 MVA three-phase banks. These units also have a fourth winding at 10 kV, delta connected to compensate for harmonic currents. Off-load tap-changers are provided on the 150 and 60 kV sides.

The 10 kV bars are supplied by two 6,000 kVA three-phase transformers, equipped with on-load tap-changers.

The switchyard is served by a central railway track, the 150 kV gear being located on one side of the track and the 220 kV and the 60 kV assemblies side by side on the other, the main transformer banks being interposed between the 220 kV and the 150 kV equipment. Connections between the transformers and the 60 kV section are in solid-type cable. The structural steelwork is of lattice construction and is galvanised. The busbars for any one voltage are arranged side by side at a common level and parallel with the railway track, the connections from the circuit breakers and isolators being brought across at a higher level. Guard wires are strung above the cross connections and are connected to the earthing system. The essential clearances are given in the accompanying Table 1.

TABLE I.—SUBSTATION LINE CLEARANCES

		220 kV	150 kV	60 kV
Distance between phases	m.	4·00	2·50	1·50
Earth clearance	m.	2·30	1·40	0·80
Height of busbars	m.	11·50	7·80	6·00
Height of connections	m.	16·00	11·50	8·30
Height of guard wires	m.	20·00	14·50	10·30

Aluminium busbars of 522 sq. mm. cross section are used for the 220 kV section, with ACSR 428·19 sq. mm. connectors. For the 150 and 60 kV sections, copper wire is used throughout, the cross sections being: 150 kV, busbars 810 sq. mm., connectors 150 sq. mm.; 60 kV, busbars 212 sq. mm., connectors 80 sq. mm.

The circuit breakers are of the minimum-oil type, those at 220 kV being arranged for rapid reclosing. The isolators are of the central rotating-post type. Both circuit breakers and isolators are operated electropneumatically from the control room.

The control room (Fig. 4) commands a view down the length of the switchyard, and contains four control desks, in two facing rows, for 220, 150, 60 and 10 kV respectively. A single-line mimic diagram of the system is formed in translucent strip on the table of each desk, and the control push buttons are at points in this diagram corresponding to the equipment they serve. These buttons as well as the strips of the diagram are translucent, and normally show a steady light; a flashing light reveals when a section of the mimic diagram does not correspond to that of the equipment. Edgewise-type instruments are mounted on the vertical portion of each desk above the corresponding part of the mimic diagram. The high-speed distance relays, which protect the lines of 220 and 130 kV network, are also installed in the control room. In the same building the load-dispatching office is located, with telemetering from Colunga sub-

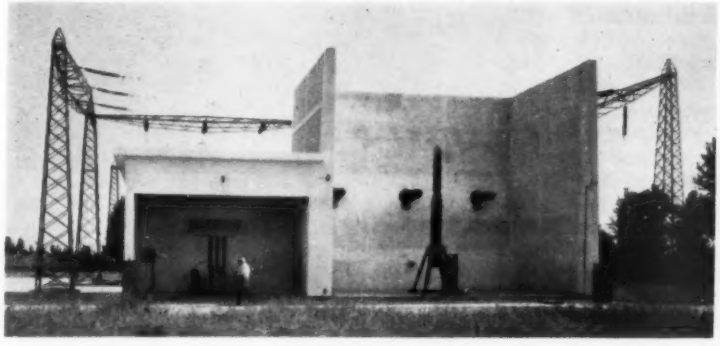


Fig. 9. Circuit-breaker test cubicles. A 220 kV minimum-oil breaker is in the larger cubicle

Fig. 10. Scorzé test station control room

station and from Soverzene power station and remote automatic control of two generator sets at Soverzene station for the combined frequency-power regulation of the SADE network.

Circuit-Breaker Testing Station

The circuit-breaker testing station, to which we have referred, is located conveniently near the switchyard, and as will be noted from Fig. 5, receives supplies at 220, 150 and 10 kV from the substation busbars. On the high-voltage circuits the supplies are controlled by high-rupturing-capacity circuit breakers, that at 220 kV having a capacity of 5,000 MVA and that at 150 kV 3,000 MVA.

Two test cubicles, depicted in Fig. 9, have been built, one for large high-voltage breakers and the other for medium-voltage breakers. The high-voltage cubicle is of the outdoor type and is 10 m. wide, 6 m. deep and 9 m. high; it can accommodate circuit breakers from 40 to 220 kV and single elements up 330 kV. The other cubicle is enclosed and measures $6 \times 3 \times 5$ m.; it can test breakers up to 44 kV.

Test current can be derived either from a transformer bank (Fig. 8) or from a special alternator. The test alternator has a nominal continuous output of 29 MVA at 10 kV, and has a short-circuit capacity of about 300 MVA. It can be used in parallel with the network or for separate tests. It is driven by a 2,000 h.p. motor at 3,000 r.p.m.

The transformer bank consists of three single-phase 500 MVA/10 sec. units, specially built to withstand short-circuit damage and having a reactance of 18% at 500 MVA. They are three-winding units with voltage ratios of 132/66/11–11 kV, the low-voltage winding being divided. Series or parallel connections can be made between the transformers to obtain a series of test voltages from 10 to 264 kV. Depending on the method of connection, the testing capacity can have values ranging up to 1,500 MVA; tests can be carried out with three-phase symmetrical, three-phase asymmetric, and single-phase supplies, and a bank of reactors with multiple taps is provided for changing the short-circuit current without modifying the general layout of the connected power network. Circuit breakers can be tested when connected to capacitative circuits, and when system conditions permit it, any length of high-voltage transmission line can be isolated for test purposes.

In addition to the building housing the test alternator, there is a main building containing the control room, laboratory and other necessary facilities. A garage in the main building accommodates an oscillograph van. Normally this van is used in the garage, but it can be taken to any part of the system to test conditions at remote points.

Contractors

The following are the principal contractors responsible for the equipment described in this article:—

Towers for lines and substations:
Societá Anonima Elettrificazione—Milano.

Insulators:
Richard Ginori—Milano.
Ceramica Italiana Laveno—Milano.

Line fittings:
A. Salvi—Milano.

Fig. 11. 130 kV transmission line in Cima Vallona pass

Line conductors:
Alluminio Società per Azioni—Lavorazione Leghe Leggere—Marghera.

Control panels and instruments at Scorzè and Colunga Substations and at Scorzè Test Station:
Officine Elettromeccaniche Galileo — Battaglia Terme.

Circuit Breakers and instrument transformers at Scorzè and Colunga:
Officine Galileo—Firenze.

Fire protection equipment for the main transformers at Scorzè and Colunga Substations:
Officine Galileo di Milano.

Protective relays at Scorzè and Colunga:
Siemens—Erlangen.
Brown Boveri—Baden.
AEG—Berlin.
ASEA—Västerås.

Main transformers at Colunga:
Marelli—Milano.
Industrie Elettriche Legnano—Legnano.

Transformers at Scorzè test station:
Indelve—Monselice (Padova).

Test generator:
Ganz—Budapest.

(To be continued)

Hydro-Electric Progress in Canada, 1957

The Water Resources Branch of the Department of Northern Affairs and National Resources has issued its annual review* of current water power development throughout Canada, and of other construction pertaining to electric power supply and distribution

CONSTRUCTION of hydro-electric plants in Canada continued to accelerate during 1957 as a result of increasing power demands. The total of 1,501,560 h.p. of new capacity added during the year represents the second highest annual increase to date. Other installations currently under construction are expected to add about 2,200,000 h.p. of new capacity during 1958 and more than 4,300,000 h.p. in the succeeding few years. The greatest increases to individual plant capacities during 1957 occurred at the Bersimis I plant of the Quebec Hydro-Electric Commission and at the Kemano-Kitimat plant of the Aluminum Company of Canada Limited, each of which brought into operation 300,000 h.p. of new capacity. In addition, there are several sites with large potential capacities, which are now under investigation and on which it is probable that development will be undertaken within a few years time. The total installed capacity of water-power plants in Canada is now listed at 19,871,008 h.p. which, however, represents less than 28% of total resources.

In addition to hydro-electric developments, the building of new thermal-electric plants and extensions was increasing in some areas of the country; the construction of main transmission lines, distribution lines and substation capacity also proceeded vigorously during the year.

British Columbia

Hydro-electric construction was very active in British Columbia, where the total of 607,500 h.p. of new capacity was the highest among the provinces. An additional 192,000 h.p. are under construction for 1958 operation and a considerable amount is in the planning or early development stages for later service.

The British Columbia Power Commission completed the installation, at its Ladore Falls development on the Campbell River, of the second of two units each consisting of a 35,000 h.p. turbine coupled to a 30,000 kVA generator. About two miles below the outlet of Upper Campbell Lake, the Commission is proceeding with its Upper Campbell Lake development, where the initial installation of a 42,000 h.p. turbine and 37,500 kVA generator is expected to be in service by May 1, 1958. Here, an earthfill dam will store water in both the Upper Campbell and Buttle Lakes for use in all three plants on the Campbell River system. Forming a part of the overall development is the diversion of flows into the Campbell River from the Quinsam, the Salmon and the Heber Rivers. The Quinsam diversion has been completed while the other two are under way. Additional construction on Vancouver Island included the commencement of a development on the Ash River, a tributary of the Stamp River, near Port Alberni. Storage and diversion dams are to be constructed at the outlet of Elsie Lake, and, by a tunnel and pipeline conduit, the water will be conducted five miles from Elsie Lake to the power house on the north shore of Great Central Lake. It is planned to install a 35,000 h.p. turbine and 28,000 kVA generator for service by March 1, 1959. Development on the mainland included the installation of a third unit at the Whatshan development near Needles, comprising a 16,500 h.p. reaction-type turbine and an 11,250 kW generator, which was completed in January 1957. In addition to the above installations completed or under way, three developments are in active prospect: two in the Alberni area of Vancouver Island, located on the Stamp and Sproat Rivers, with potentials of 35,000 h.p. and 17,000 h.p. respectively, and the third on the Kokish River in the Englewood area in upper Vancouver Island, with a potential of 51,500 h.p. Four additional possible developments are under active study and investigation by the Commission; one on Vancouver Island with a potential of 81,500 h.p. on the Nimpkish River in the Englewood area; the remaining three on the mainland and consisting of a development of up to 1,900,000 h.p. by diverting water from the Chilko to the Homathko Rivers, a second development at Helmcken Falls on the Murtle River, tributary to the Clearwater River, with a potential of 140,000 h.p., and the third at Hobson Lake, also in the Clearwater River system, with a potential of 120,000 h.p. Dam foundation drilling has been carried out in connection with the Chilko-Homathko and the Nimpkish developments.

The British Columbia Electric Company Limited commenced operation of its Cheakamus development in October when the first of two units, each comprising a 95,000 h.p. turbine and 80,000 kVA generator, was brought into service, and the second unit added about a month later. The project consists of a dam on the Cheakamus River near Garibaldi and a tunnel 18 ft. in diameter, 6¾ miles in length, which diverts water to the power house on the Swamish River. With a maximum height of 91 ft., the dam creates a reservoir having a capacity of 40,000 acre-ft. The development at Clowhom Falls on Sechelt Peninsula, purchased in 1956 from the British Columbia Power

* Copies may be obtained free of charge from the Director, Water Resources Branch Department of Northern Affairs and National Resources, Ottawa.

Commission, was rebuilt and the 4,000 h.p. two-unit installation replaced by a single unit consisting of a 40,000 h.p. turbine and 31,500 kVA generator. The concrete gravity dam was raised to a maximum height of 71 ft., creating a reservoir with a capacity of 77,000 acre-ft.

At the Company's Bridge River system, the power plant at the La Joie dam commenced operation in November when a 30,000 h.p. turbine and 24,500 kVA generator were placed in service. The single unit, located on the downstream end of one of the two existing outlet tunnels, will utilise the water as it is released from the La Joie reservoir for further use at the downstream Bridge River and Seton Creek plants. Work was continued on the final phase of the Bridge River development involving a large storage dam, a second tunnel through Mission Mountain and a new power house, Bridge River No. 2, on Seton Lake about one-half mile upstream from the present plant. The storage dam, in the vicinity of the existing diversion dam, will provide an additional 750,000 acre-ft. of storage, bringing the total capacity of the two reservoirs to 1,335,000 acre-ft. The new dam will raise the head on the existing power plant on Seton Lake and is expected to increase the total capacity of the four units in this plant from 248,000 h.p. to 276,000 h.p. At the Bridge River No. 2 development, four units, each consisting of an 82,000 h.p. turbine and 65,500 kVA generator, are expected to be installed during the latter half of 1959, which will provide a total installed plant capacity of 328,000 h.p.

The Aluminum Company of Canada Limited installed the fifth and sixth units, each of 150,000 h.p., in its Kemano plant, bringing the total capacity to 900,000 h.p. The installed generator capacity is 750,000 kVA. It is expected that a seventh unit, also of 150,000 h.p., will be installed early in 1958.

The Consolidated Mining and Smelting Company of Canada Limited commenced field investigation, involving geological mapping and preliminary drilling, at the second power site on the Pend d'Oreille River, located about six miles upstream from its Waneta plant.

The West Kootenay Power and Light Company Limited was expected to complete and energise before the end of 1957 a 138 kV transmission line between its plant at South Slocan and the Whatshan plant of the British Columbia Power Commission. It also has completed a 20 kV line between the South Slocan plant and Slocan City, which will provide power service in the Slocan Valley.

Alberta

In October, Calgary Power Limited completed and placed in service a second unit at its Cascades plant. The new unit, to be used mainly for peak-load purposes, consists of a 23,000 h.p. Francis turbine which operates under a head of 320 ft. and is connected to a 20,000 kVA generator. The Company has begun construction of extensions to its Spray and Rundle plants in the Spray Lakes development, which will approximately double the capacity of the existing development. A second 62,000 h.p. unit is being added to the Spray plant and a 40,000 h.p. unit to the Rundle plant, both of which are scheduled for completion in October 1959. Preliminary investigations are being continued by the Company for a possible development at its Big Bend site on the Brazeau River, where a gauging station has been established. At the Big Horn site, on the North Saskatchewan River below Tershishner Creek, and at other nearby sites on that river, investigations for power development were suspended when exploratory drilling revealed disappointing foundation conditions.

The Alberta Power Commission reports that 39,812 farms in Alberta were receiving electric service on September 30, 1957, and estimates that a total of about 40,000 farms will have been connected by the end of the year. Of this total, Calgary Power Limited serves about 29,000, Canadian Utilities Limited about 9,340, Northland Utilities Limited about 1,400, the City of Edmonton 142, and the East Kootenay Power Company Limited 117 in the extreme south-western part of the province. During 1957 about 3,200 of these farms received their initial electric service.

Manitoba

The Manitoba Hydro-Electric Board is proceeding with the construction of its development on the Nelson River at Grand Rapid, located about 400 miles north of Winnipeg, to supply power for the International Nickel Company mining development at Moak, Mystery and Thompson Lakes. The power plant, which is to be named the Kelsey Generating Station, will be located upstream from Grand Rapid on a peninsula forming the west shore of the river, and will discharge water into Split Lake. The initial installation is to comprise four 42,000 h.p. propeller-type turbines operating under a normal head of 50 ft., each coupled to a 37,500 kVA generator operating at 90% power factor. Two of these units are scheduled for operation by July 1, 1960, and the remaining two by January 1, 1961. Additional features of construction include the excavation of a channel on the east side of the river to divert the entire flow of the Nelson River around Grand Rapid, the construction of a 1,400 ft. rockfilled cofferdam and of a permanent dam which will provide a mean head of 55 ft. Other work related to the project includes a cantilever bridge, 248 ft. long, and 14 miles of railway track between the contractor's site and the Canadian National Railway line at Mile 256.

Sherritt-Gordon Mines Limited have completed the Laurie River No. 2 development, comprising one 7,000 h.p. Francis turbine operating under a head of 55 ft. and connected to a 6,000 kVA generator. This plant is connected to the downstream No. 1 plant by 5 miles of 69 kV transmission line and is to be automatically controlled from that plant. Concrete sluicegate sections of the storage dams at the outlets of Eager and Russell Lakes were completed in July 1957.

The City of Winnipeg is continuing with the renovation of its Pointe du Bois hydro-electric station and made repairs to the spillway and sluice gates at the Slave Falls station, both on the Winnipeg River. Two new substations in the Winnipeg area with capacities of 15,000 and 13,334 kVA, both reducing from 60 kV to 4·16 kV, are being constructed for operation by January 31, 1958.

The Manitoba Power Commission, which distributes electrical power throughout the province except for the City of Winnipeg, completed during the year, or has under construction, about 150 circuit miles of transmission and tie lines with capacity 22 kV or greater, of which 22 miles were changed over

from 33 kV to 66 kV. During the year, service was extended to approximately 450 farms and 6,200 residential and commercial customers throughout suburban Winnipeg and rural Manitoba. Substation and terminal station capacities were increased by 47,363 kVA and 33,750 kVA respectively.

Ontario

Demands for power throughout past years have resulted in an intensive construction programme by The Hydro-Electric Power Commission of Ontario as a result of which a substantial growth in power requirements has been met successfully. Major construction work during 1957 included developments at the St. Lawrence Power Project, at Sir Adam Beck-Niagara Generating Station No. 2, and at six projects in north-western Ontario.

Field investigations of new hydraulic sites were carried out in northern areas of the province during the year. The Commission also completed construction of a canal and control works for the diversion of water from Lake St. Joseph in the Albany River drainage to Lac Seul in the English River drainage via the Root River.

The St. Lawrence power project, a joint development of the International Rapids Section of the St. Lawrence River, was begun in August 1954 by The Hydro-Electric Power Commission of Ontario on the Canadian side of the river and by the Power Authority of the State of New York on the United States side. The main features of the project include two adjoining power houses which form an integral part of a gravity-type dam structure, a dam at Long Sault to control the level of the headpond, a dam at Iroquois Point to regulate flow from Lake Ontario, and some 14 miles of dyke. Other work related to the project included channel improvement and excavation, the relocation of highways, railways, transmission facilities, and the design and construction of new town sites.

Excellent progress was made on all phases of construction throughout 1957. On the Canadian side, concrete for the main dam and power-house structure was placed even during the coldest winter months, and at the end of the year more than 86% of all concrete work was completed. Mechanical equipment for the sixteen generating units was partly installed, and by fall, crews had begun the assembly of the generator for the first unit. Five of the sixteen units were scheduled for service in 1958; the rest will be placed in service during the period 1959–1960. The total installed capacity of the turbines will be 1,100,000 h.p. A temporary navigation canal by-passing the main construction area on the Canadian side was completed and opened to shipping in April 1957. The canal provides passage for ships through the Cornwall section of the headpond dyke, where a concrete closure structure has been established for the purpose of closing this channel when the headpond is raised. The Cornwall dyke was substantially completed in October when the last of some 5 million cu. yards of earthfill was placed and compacted. Only protective riprap remains to be placed. The headpond itself will be established in the summer of 1958 following the closure of the Long Sault dam. Heavy dredges deepened and enlarged channels in the vicinity of Chimney and Galop Islands and at Iroquois Point. Additional excavation was begun during the year in three other areas, near Three Points, Morrisburg, and Cardinal. Communities living in areas to be flooded along the north shore of the river were moved to new locations. Three new townsites were created to accommodate people from these areas. A section of double-track railway, approximately 40 miles in length, and 35 miles of main highway were also relocated on higher ground.

At the Sir Adam Beck-Niagara Generating Station No. 2, on the Niagara River, the Commission amended its 1953 plans to provide for an associated pumping-generating station and four additional units at the main station. Construction for the pumping-generating station was begun the following year, and the installation of the four main generating units was begun in 1955. By the end of 1957 work on both these projects was well advanced. At the main generating station two of the additional units were placed in service in December. Work on the final two will be largely completed in the spring and the units will be placed in service in May and July of 1958 respectively. Each of the four units, like the twelve already in operation, has a rated capacity of 105,000 h.p. At the pumping-generating station three units of the six units planned were placed in service in the latter part of 1957. During periods of low demand the units will pump water diverted from the main power canal into a reservoir having a capacity of some 16,000 acre-ft. In periods of high demand they will operate in reverse as turbines, each unit having a capacity of 47,000 h.p. at maximum discharge of 5,600 cusecs. Flow from the reservoir in turn will augment the flow in the power canal and thus increase the output of the units in the main generating station. Work on the installation and assembly of the generators for the three remaining units progressed favourably. They are expected to be in service in the spring of 1958.

Marking the fulfilment of the Niagara River remedial works programme, the construction of a control dam in the Niagara River about a mile upstream from the falls was completed in the early part of the year and the last four gates were placed in operation. The completed dam with its 14 concrete piers incorporates 13 sluiceways, each 100 ft. in width and equipped with bascule-type submersible gates. A service deck 1,500 ft. in length spans the structure. Other portions of the remedial works involved the excavation of certain areas of the river-bed and the placing of fill on the United States side of the river; this was carried out by the United States Army Corps of Engineers in 1954, and similar work on the Canadian side was carried out by the Commission in 1955.

The development of Whitedog Falls on the Winnipeg River was undertaken by the Commission in 1955 and considerable preparatory work was carried out at the time and during the following year. The total turbine capacity will be 81,000 h.p. and initial service was scheduled for February 1958. At the end of 1957, construction of the main dam for the three-unit generating station was substantially completed. The dam incorporates a power house, adjoining headworks, and a sluiceway structure with nine sluice-gates, two of them motor-operated. It extends some 1,150 ft. across the south channel of the river at Whitedog Island. By the end of the year the dam, including the south bulkhead, gate sluices, log-chute head-block, and a compacted earthfill wing dam on the north shore, has been completed. Mechanical

equipment for the two motor-operated sluice-gates was installed also. Concrete placing in the power-house structure was completed and work crews began the assembly and erection of turbines and generators.

The construction of the Caribou Falls generating station was commenced by the Commission in 1956. It is located in the north-western section of the province, on the English River about 17 miles north-west from Whitedog Falls. Early in 1957 the power-house site was dewatered and excavation was begun for a main dam structure which will extend 1,260 ft. across the river. By the end of the year much of the new station had taken shape. East and west bulk-heads and the erection bay were built and concrete was placed for piers and sluices in the headworks area. In the power-house area the structural work for the first unit was almost complete and the installation of the turbine and generator was started. In addition to this work, four auxiliary block dams were built which will assist in containing the headpond where contours are below the desired maximum water-level. Clearing of trees and brush from the headpond was finished early in the fall. Only salvaged pulpwood remains in the area, cut and piled ready for moving. At the Manitou Falls generating station, provision for the installation of a fifth unit was made in the headworks in the event of increases in loads in the north-western section of the province. By late spring in 1956 it was apparent that the output of an additional 18,500 h.p. unit would be required. Therefore in the spring of 1957 the Commission began work on this installation and such excellent progress was made during the year that the expected service date was advanced to March 1958.

In its Cameron Falls and Alexander generating stations, on the Nipigon River, the Commission began work on the installation of two additional units in 1956. At the Cameron Falls station a 25,000 h.p. unit will be housed in a separate structure east of the present six-unit power house. During 1957 the site was dewatered and work on the structure was carried out. By the end of the year this work was near completion and the turbine for the unit was partially assembled. At the Alexander Falls station a 19,000 h.p. unit will be housed in an extension to the present main structure. Although construction was hampered by deep water as well as by cold weather, the turbine was installed and the generator was partially assembled by the end of the year. Both additional units are expected to be in service by mid-1958.

In February 1957 the Commission undertook the development of a single-unit station at Silver Falls on the Kaministikwia River in north-western Ontario. The new station is scheduled for service in September 1959. It will consist of an intake structure and tunnel which will convey water some 9,000 ft. to a power house housing a 60,000 h.p. unit. The tunnel, about 14 ft. in diameter and lined with concrete, will be provided with a surge tank. Preparatory work at the site began early in the year. By December an access road had been built and about 1,500 ft. of tunnel had been driven.

During 1957, the Commission increased its mileage of in-service transmission and rural distribution lines as follows: 47 circuit miles of 230 kV line, 259 circuit miles of 115 kV line, 166 circuit miles of 13 to 14 kV line and 861 circuit miles of rural distribution line. It is estimated that at the end of 1957 the total number of rural customers served by the Commission was 454,000, including about 140,900 farm customers.

Apart from the activities of the Commission, the Great Lakes Power Company Limited placed in operation on April 8, at its Upper Falls plant on the Montreal River, a new unit comprising a 30,000 h.p. turbine driving a 25,000 kVA generator. Total plant capacity is now 55,300 h.p. The dam at this site had been raised previously by 33 ft. to a height of 86 ft. above the river bed, providing an average operating head of 232 ft. The Company also is proceeding with two other hydro-electric developments; one on the Montreal River at Centre Falls, where one unit of 30,300 h.p., under a head of 115 ft., driving a 22,222 kVA generator, will come into operation about April 1, 1958, and the other on the Michipicoten River at Cat Falls, having similar turbine and generator ratings, but with an average operating head of 100 ft., and scheduled for operation in May 1959.

Quebec

The Province of Quebec continued its extensive hydro-electric power activities with a net capacity increase during 1957 of 473,900 h.p. after allowing for the dismantling of 10,100 h.p. of capacity. In addition, new capacity currently under construction will add about 900,000 h.p. during 1958 and more than 2,700,000 h.p. in later years.

The Quebec Hydro-Electric Commission completed the installation of the fourth and fifth units in its Bersimis I development some 300 miles north-east of Montreal, raising the installed capacity of the plant to 750,000 h.p. Each unit is rated at 150,000 h.p. and operates under a head of 875 ft.; power is delivered to the new Bont-de-l'Ile substation on the Island of Montreal. The ultimate capacity of the underground power house will be 1,200,000 h.p. in eight units. At Bersimis II, about 23 miles downstream, good progress was achieved in the preliminary stages of construction. The project involves the excavation of an intake tunnel 4,000 ft. long and a diversion tunnel about 1,100 ft. in length, the erection of two dams—one of concrete and the other of rockfill—and the construction of 60 miles of road. The power house will have a total installation of 855,000 h.p. in five units, each turbine being rated at 171,000 h.p. under a head of 375 ft.

At the Beauharnois development on the St. Lawrence River, some 30 miles from Montreal, the Commission proceeded with the construction of the third and final section of the power house which will contain 11 units, each of 73,700 h.p., under a head of 80 ft. Dredging operations were continued towards the enlargement of the intake canal. Initial operation of this section is expected late in 1958 and the completion of the entire plant, with a total installed capacity of 2,235,000 h.p., in 1960.

Among other activities of the Commission, the construction of a storage dam at the outlet of Lake Ste. Anne on the Toulnoustouc River, a tributary of the Manicouagan River, is nearing completion. This dam will allow a higher firm output from the plant of the Manicouagan Power Company, which is installing additional capacity to meet the initial power requirements of the Canadian British Aluminum Company plant near Baie Comeau. Studies and surveys are being carried out for developments in the Lachine Rapids section of the St. Lawrence River and in the

Manicouagan region on the north shore of the St. Lawrence River. In the field of transmission, progress was made on the construction of three additional 300 kV lines—Labrieville to Quebec City, Labrieville to Hauterive (near Baie Comeau) and a tie line between the plants Bersimis I and Bersimis II.

Price Brothers Co. Ltd. placed in service on September 21 its new Murdock-Willson power development located at the mouth of the Shipshaw River just below Willson Falls. The plant contains one 82,000 h.p. turbine, under a head of 265 ft., connected to a 70,000 kVA generator, and is remotely controlled from the Company's substation in the Kenogami paper mill three miles away. The Company's existing 10,100 h.p. Murdock plant, which was taken out of service on October 20, will be abandoned. A new 3-mile 69 kV transmission line has been constructed between the Murdock-Willson power house and the Kenogami paper mill.

The Manicouagan Power Company is meeting its construction schedule on its McCormick Dam Project No. 2, which is an extension of the Company's Manicouagan River plant at First Falls near Baie Comeau. The first of three additional units (Nos. 3, 4 and 5), each comprising a 60,000 h.p. turbine under a head of 124 ft. and a 40,000 kVA generator, was placed in operation on December 6. Units Nos. 4 and 5 are expected to be installed early in 1958. The Company's 161 kV transmission line from the McCormick Dam substation to the Canadian British Aluminum Company smelter plant at Baie Comeau was placed in service on November 5. To provide additional power for the smelter plant, the Company is arranging to build another 161 kV line, 3¼ miles long, from its 161 kV substation at Manicouagan to the Quebec Hydro-Electric Commission's substation at Hauterive.

The Eastern Smelting and Refining Company Limited completed construction and placed in operation on May 17 its hydro-electric plant on the Chicoutimi River at Chicoutimi. The plant contains a 42,000 h.p. turbine, under a head of 273 ft., with a 40,000 kVA generator, and power is supplied to the Company's nearby smelter by a one-mile 161 kV line.

The Aluminum Company of Canada Limited proceeded with the construction of its development on the Peribonka River at Chutes des Passes, which will contain five units at 200,000 h.p. each, to be operated under a head of 625 ft. The first unit is expected to commence service in the autumn of 1959. Two transmission line circuits eventually will tie the Chutes des Passes station with the Company's present network at Isle Maligne. Work is progressing, and is expected to be essentially completed in 1958, on a project to divert water from Manouan Lake into the Bonard River, which empties into the Peribonka River above Passe Dangerouse.

The Shawinigan Water and Power Company made good progress on the construction of its 330,000 h.p. development on the St. Maurice River at Rapide Beaumont, 10 miles upstream from La Tuque. The plant will comprise six 55,000 h.p. turbines, operating under a head of 125 ft., and driving 45,000 kVA generators, initial operation being scheduled for November 1958. Extension to the Company's transmission system consisted of 16 miles of 66 kV line between St. Adrien and Weedon. At present, a total of 42,325 farms receive power from the Company.

The James Maclaren Company Limited, which is affiliated with the Maclaren-Quebec Power Company, is building, for completion in 1959, a hydro-electric station of 50,000 h.p. on the Lievre River at Dufferin Falls in Buckingham.

The Gatineau Power Company is converting all of its 25 cycle equipment to 60 cycles. Construction was started on a new 240 kV line from Lachute to St. Jerome to be operated initially at 115 kV. A new 69 kV line, to be operated initially at 26·4 kV, was completed from St. Jovite to Arundel. Rural distribution circuits were extended for 91·8 miles and 8,802 farms now receive electrical power from the Company.

The lower St. Lawrence Power Company completed three 5,000 kVA distribution substations at Mont Joli, Rimouski and Matane. Twelve miles of distribution line were added during the year and a 45-mile 161 kV transmission line between Les Boules and Causapscal has now been placed in service, to be operated initially at 69 kV. A total of 8,476 farms are now served by the Company.

The Southern Canada Power Company placed in service 17·8 miles of 110 kV transmission line between Magog and Bromptonville to tie in with the Shawinigan system, together with another 16 miles of 48 kV line. Rural and distribution mileage has increased by 17·0 and 20·0 miles respectively.The total number of customers has increased to 83,051, of which 12,693 are farms. The Company has discontinued the use of its 800 h.p. hydro-electric plant on the Yamaska River at Farnham.

Other power-producing agencies carried out extensions to their transmission and distribution systems. The Quebec Power Company completed a 24-mile single-circuit 66 kV transmission line between Quebec City and Beaupre. About 9,340 farms were receiving electrical service from the Company at the end of the year. The Shawinigan Engineering Company is preparing plans and specifications for the City of Sherbrooke for constructing a 110 kV substation to consist of two regulation transformers, 30,000 and 40,000 kVA respectively, 110/48 kV, to receive power from the Shawinigan Water and Power Company transmission system. The Northern Quebec Power Company Limited was serving 237 farms at the end of the year.

The Quebec Department of Hydraulic Resources, through its extensive system of storage reservoirs, successfully maintained regulation of flow for power production and flood control on a number of important rivers.

New Brunswick

The New Brunswick Electric Power Commission placed on test, on November 4, the first unit of its Beechwood development on the Saint John River, with the second unit scheduled for completion by January 31, 1958. Provision has been made for the installation of a third similar unit. Each unit consists of a 45,000 h.p. turbine under a head of 60 ft., driving a 40,000 kVA generator. During the year, the Commission extended its transmission facilities by 68·4 miles of 138 kV line from the Beechwood plant to Fredericton and 30·4 miles of similar line from Fredericton to Grand Lake, Queen's County, in addition to which 59 miles of 69 kV transmission line and 121·1 miles of rural distribution line were completed. About 190 miles of additional 138 kV transmission line are at present under construction. The Moncton Ter-

minal and Grand Lake Terminal substations, each rated at 50,000 kVA, were completed on October 31, while another substation of 10,000 kVA capacity is currently under construction at Moncton. Electrical service was extended to 1,000 farms, making a total of about 26,000 farms supplied by the Commission.

Nova Scotia

The Nova Scotia Power Commission completed in August its Bear River plant at Bear River, Annapolis County, with one 5,300 h.p. turbine under a net head of 142 ft., operating a 4,000 kW generator. A 25,000 h.p. development on the Sissiboo River near Weymouth, Digby County, is in active prospect and investigations are proceeding with respect to the Commission's proposed Wreck Cove development on Cape Breton Island. During the year, extensions to the transmission system included 61·0 miles of 69 kV line and 17·0 miles of 23 kV line; 18·0 miles each of 69 kV and 23 kV line are under construction. There were 30·6 miles of rural distribution lines completed and electric service was extended to 448 farms, raising the total of farms connected to about 18,840. The Commission completed substations at Trenton, Onslow in Colchester County and Whycocomagh, Inverness County, the capacities being 15,000, 3,750 and 3,000 kVA respectively. Two additional substations, each of 5,000 kVA capacity, are under construction at Blockhouse and Bridgewater in Lunenburg County.

The Nova Scotia Light and Power Company Limited has under construction, at its Hemlock Falls plant on the Avon River at Windsor Forks, a 5,000 h.p. unit which, late in 1958, will replace the existing two units of 1,150 h.p. each. The Company has dismantled its 360 h.p. plant on the East River at Chester. In active prospect is a 6,500 h.p. development on the Mictaux River at Alpena, although no construction dates have yet been set. Nineteen miles of 23 kV transmission line were completed during the year, while 23 miles of 69 kV line and 5 miles of 23 kV line are under construction for operation early in 1958.

Newfoundland

The Maritime Mining Corporation Limited have completed at Venams Brook, Green Bay, a 460 h.p. unit, operating under a head of 229 ft. In August a 760 h.p. unit, under a head of 241 ft., was installed on Snooks Arm at Green Bay.

The Bowater Power Company Limited is continuing the construction of its hydro-electric development at Corner Brook, where two 6,000 h.p. turbines, under a head of 526 ft. and connected to two 5,100 kVA generators, are expected to commence operation early in 1958. In the Grand Lake Watershed, Newfoundland, two developments are in active prospect; one on Hinds Brook consisting of two units developing a total of 50,000 h.p. under a head of 679 ft., and the other on Little Grand Lake to consist of a 14,000 h.p. unit under a head of 205 ft.

The Newfoundland Light and Power Company Limited is scheduled to have in operation, late in 1958, a new hydro-electric plant on Rattling Brook near Norris Arm. It will have a total of 17,000 h.p. in two units operating under a head of 307 ft.

The Union Electric Light and Power Company Limited is expanding its Trinity River hydro-electric plant near Trinity by the addition of a 2,000 h.p. unit, under a head of 260 ft. Completion is expected in 1958. The Company is currently constructing 33 miles of 48 kV transmission line between Lockston and Clarenville, Trinity Bay.

The United Towns Electric Company Limited is adding a third unit of 3,600 h.p. capacity to its hydro-electric plant at Lookout Brook. The unit will operate at a head of 550 ft. and, when completed in 1958, will increase total installed capacity of the plant to 7,300 h.p.

The British Newfoundland Corporation Limited is actively considering a hydro-electric development at Bay d'Espoir in the central part of Newfoundland, where 350,000 h.p. may be developed under a head of about 530 ft. In connection with its proposed Hamilton River power site, in Labrador, the Corporation completed the all-weather access road from Mile 286 on the Quebec-North Shore and Labrador Railway to the Hamilton River and surveyed the small remaining section leading to the selected power-house site.

Yukon and North-West Territories

To encourage the development of the resources of Northern Canada, the Federal Government established in 1948 the Northern Canada Power Commission, an agency for the construction and management of electric power utilities. The Deputy Minister of Northern Affairs and National Resources is Chairman of this Commission and the Director of the Water Resources Branch is a member.

Hydro-electric construction activities of the Commission during 1957 were confined to the Yukon Territory. These included the installation of a second 3,000 h.p. unit at its Mayo River hydro-electric plant, which was put into operation in December; also steady progress has been made on the development of Whitehorse Rapids, on the Yukon River,, from Whitehorse, where the initial installation is scheduled for completion in the autumn of 1958 and will consist of two 7,500 h.p. Kaplan units under a head of 63 ft. Provision is being made for the installation of a third unit.

British Electrical Conference at Brussels

Overseas registrations for the 1958 British Electrical Conference at the Brussels World Exhibition have been received, and there has been a good response from the United Kingdom. Those intending to attend the Conference and who have not yet registered are asked to do so without delay, particularly if they require the reservation of hotel accommodation. Full details of the Conference together with registration forms and hotel booking forms are obtainable on request from the Organising Secretary, 1958 British Electrical Conference, 36 Kingsway, London, W.C.2. The Conference will be held in the Exhibition Auditorium at Brussels on May 16 and 17, and papers will be read by Sir Gordon Radley, Director General of the British Post Office, on "Communication Between Nations and Peoples," and by Sir John Cockcroft, Director, Atomic Energy Research Establishment, Harwell, on "Nuclear Energy, the Power of the Future." The President of the Conference will be Sir Vincent de Ferranti, and many leading personalities in the electrical world have agreed to serve as Vice-Presidents.

Vibration Tests on Weirs and Bottom Gates

By DR. ING K. PETRIKAT, Chief Engineer and Head of the Hydraulic Laboratory, Maschinenfabrik, Augsburg-Nürnberg A.G. Gustavsburg Works

PART TWO

Vibration data for an elastic plate flap (Figs. 12 and 13, a, b, c).

(A) SINGLE-MEMBER OSCILLATING SYSTEM (FLAP ONLY)

$s=0{\cdot}595$ (m.).
Width of model flap in the test.
Flume of 0·6 m. (2 ft.) width.

$l=0{\cdot}17$ (m.).
Length of flap from axis of rotation to overflow edge.

$\phi=\phi_{max}\sin\omega t$.
Angle of rotation of oscillating flap.

$\phi_{max}=0{\cdot}012=\phi_o$.
Maximum angle of rotation with the induced flap oscillation observed.

$\frac{d\phi}{dt}=+\phi_o\,\omega\cos\omega t$.
Flap speed.

$\frac{d^2\phi}{dt^2}=-\phi_o\,\omega^2\sin\omega t$.
Flap acceleration.

$n=6{\cdot}9\ (s^{-1})$.
Frequency of induced flap oscillation.

$T=0{\cdot}145$ (s).
Period of oscillation.

$\omega=43\ (s^{-1})$.
Cyclic frequency.

$h_o=0{\cdot}027$ (m.).
Depth of water nappe flowing over flap.

$c=5{\cdot}8$ (kg. m.).
Spring constant of flap.

$M\,d_3=-c\,\phi$ (kg. m.).
Moment of elasticity.

$n_1=8{\cdot}5\ (s^{-1})$.
Natural frequency of flap in free oscillation test (no coupling of oscillating system).

$\omega_1=53\ (s^{-1})$.
Cyclic frequency (no coupling of oscillating systems).

$$J_1=\frac{c}{{\omega_1}^2}=\frac{5{\cdot}8}{53^2}=0{\cdot}002\Gamma.$$

$$Md_1=-J_1\frac{d^2\phi}{dt^2}\text{(m. kg.)}.$$

Moment of inertia of the flap and the mass of water participating in the oscillation.

$$\delta_1=ln\frac{\phi_1}{\phi_2}=ln\,1{\cdot}75=0{\cdot}56.$$

Damping of the overshot flap from amplitude ratio.

$$W_1=\frac{\delta_1\,\omega_1\,J_1}{\pi}=\frac{0{\cdot}56\times53\times0{\cdot}0021}{3{\cdot}14}=0{\cdot}02.$$

Damping coefficient of overshot flap, inclusive of damping resulting from coupling.

$$J_o=\frac{c}{{\omega_o}^2}=\frac{5{\cdot}8}{66^2}=0{\cdot}0013\ \text{(kg. m. s}^2\text{)}$$

Moment of inertia of the flap without water.

$\omega_o=66\ (s^{-1})$.
Cyclic frequency, free oscillation test without water.

$$W_o=\frac{\delta_o\,\omega_o\,J_o}{\pi}=\frac{0{\cdot}1\times66\times0{\cdot}0013}{3{\cdot}14}=0{\cdot}0027.$$

Damping coefficient of the flap without water.

$$\Delta p_{\min}=\frac{\phi_o\,\omega\,W_1\,2}{s\,l^2}\text{(kg. m.}^{-2}\text{)}.$$

$$\Delta p_{\min}=\frac{0{\cdot}012\times43\times0{\cdot}02\times2}{0{\cdot}595\times0{\cdot}17^2}=1{\cdot}2\ \text{(kg. m.}^{-2}\text{)}.$$

Peak value of periodically reversing pressure differential below the weir which is sufficient to make the flap oscillate when its phase is in opposition to the damping.

$n_p=1{\cdot}1$.
Exponent for polytropic compression.

$$\Delta p=\frac{\Delta v\,p_m\,n_p}{v_m}=\frac{0{\cdot}0002\times10^4\times1{\cdot}1}{0{\cdot}15}$$

$\Delta p=14$ (kg. m. $^{-2}$).
Pressure pulse theoretically determined from the undulation pattern, assuming polytropic homogeneous pressure conversion (Fig. 12).

$$\Delta p=\frac{\Delta v\,p_m\,n_p}{v_m}=\frac{0{\cdot}25}{42}\times10^4\times1{\cdot}1.$$

$\Delta p=65$ (kg. m. $^{-2}$).
Pressure pulse determined from photograph.

$\Delta p=4{\cdot}5$ (kg. m.$^{-2}$)
Maximum measured pressure differential—oscillogram (Fig. 14).

$$Md_4=\Delta p\frac{l^2}{2}s\cos\omega t=$$

$$=c_3\frac{d\phi}{dt}=\frac{4{\cdot}5\times0{\cdot}17^2\times0{\cdot}595}{2\times0{\cdot}012\times43}\times\frac{d\phi}{dt}=0{\cdot}075\frac{d\phi}{dt}$$

Vibration inducing moment set up by the pressure differential due to undulation.

(B) COUPLED OSCILLATING SYSTEM (FLAP/AIR-SPACE/WATER-NAPPE)

$Md_5=c_2\,x$.

$$Md_5=\frac{l^2\,s\,p_m\,n_p\,F\,x}{2\,v_m}$$

$$c_2=\frac{0{\cdot}17^2\times0{\cdot}595\times10^4\times1{\cdot}1\times0{\cdot}45}{2\times0{\cdot}15}=280.$$

Moment acting on the flap originating from water overfall movement in direction (coupling moment).

$x = x_o \sin(\omega t + \beta)$.

Movement of total water nappe in x direction. x_o peak value of deflection of water nappe from mid-position. β phase shift on encounter of water nappe and flap.

$\frac{dx}{dt} = x_o\,\omega \cos(\omega t + \beta)$.

Speed of nappe in x-direction.

$\frac{d^2x}{dt^2} = -x_o\,\omega^2 \sin(\omega t + \beta)$.

Acceleration of nappe in x-direction.

$P_1 = -m\frac{d^2x}{dt^2}$

Force of inertia.

$m = \frac{\delta_s F \gamma_m}{\delta} = 0{\cdot}17$ (kg. m. $^{-1}$s^2).

Mass of jet.

$\delta_s = 0{\cdot}0037$ (m.).

Mean thickness of jet (Fig. 12).

$P_2 = -\sigma\frac{dx}{dt}$

Damping force.

$\sigma = \frac{m\,\delta\,v_B}{\pi} = \frac{0{\cdot}17 \times 0{\cdot}1 \times 302}{3{\cdot}14} = 1{\cdot}6.$

Damping coefficient.

$\delta = 0{\cdot}1$.

Damping of a surface by the ambient air, similar to the decay of plate flap oscillation in air.

$v_B = \sqrt{\frac{d_1}{m}} = \sqrt{\frac{15{,}500}{0{\cdot}17}} = 302$ (s^{-1}).

Natural frequency of the air-space/water-nappe system.

$n_B = \frac{v_B}{2\pi} = 48$ (s^{-1}).

Number of oscillations.

$P_3 = -d_1 x$.

Elastic restoring force due to compression of the air under the water jet.

$d_1 = \frac{F^2\,p_m\,n_p}{v_m} = \frac{0{\cdot}45^2 \times 10^4 \times 1{\cdot}1}{0{\cdot}15}$

$d_1 = 15{,}500$.

Elasticity coefficient of air space.

$P_4 = d_2\,\phi = \frac{l^2\,s\,p_m\,n_p\,F\,\phi}{2\,v_m}$

Force exerted by the flap on the water nappe due to compression of the air below the flap caused by rotation of flap ϕ.

$d^2 = \frac{l^2\,s\,p_m\,n\,F}{2\,v_m}$

$d^2 = \frac{0{\cdot}17^2 \times 0{\cdot}595 \times 10^4 \times 1{\cdot}1 \times 0{\cdot}45}{2 \times 0{\cdot}15}$

Coefficient of flap influence.

$P_4 = 280\,\phi$.

$\eta_K = 0{\cdot}5$ to $1{\cdot}0$.

Factor of coupling to take account of uneven pressure due to non-uniformity of pressure distribution.

$P_5 = -\Delta p\,F \cos \omega t.$

$= -d_3\frac{d\phi}{dt}$

Oscillation-inducing force set-up by pressure differential due to undulation.

$d_3 = \frac{\Delta p\,F}{\phi_o\,\omega} = \frac{4{\cdot}5 \times 0{\cdot}45}{0{\cdot}012 \times 43} = 3{\cdot}9.$

Coefficient of oscillation-inducing force with the peak value Δp in opposition to flap damping, a frequency of $\omega = 43$ and deflection of $\phi_o = 0{\cdot}012$.

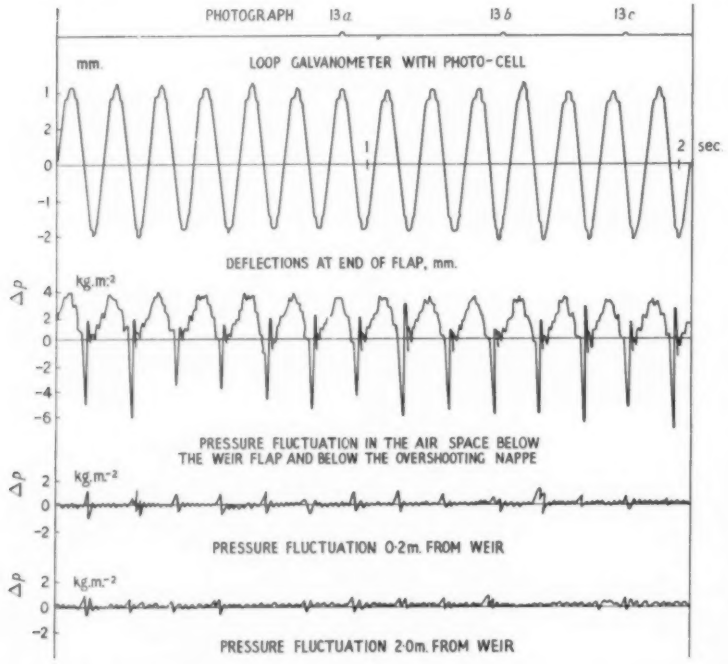


Fig. 14. Oscillogram of oscillating overshot model flaps showing pressures below the weir and at a distance of 0·2 m. and 2 m. from the weir

The computations and photographs show that the change in volume, and hence the pressure, caused by the undulation, may increase considerably so that the amplitude of flap oscillation should have been greater. However, since the jet was barely 2 mm. thick in its lower part, its splitting in the region close to the tailwater prevented the formation of higher pressure. Oscillation was observed throughout the tailwater level range from 0·00 to 0·41 m. (Fig. 12). As the tailwater level rose further, the moments caused by undulation were co-directional with the damping and no oscillation was induced in this range. A further rise in tailwater level resulted in another phase in the volume and pressure change in which the oscillation-inducing moment exceeded the damping, and the flap was again caused to oscillate. This simple form of presentation explains the essential phenomena of oscillation of overshot weirs. However, a comprehensive study of the subject requires that the effects of coupling between the flap, the air space

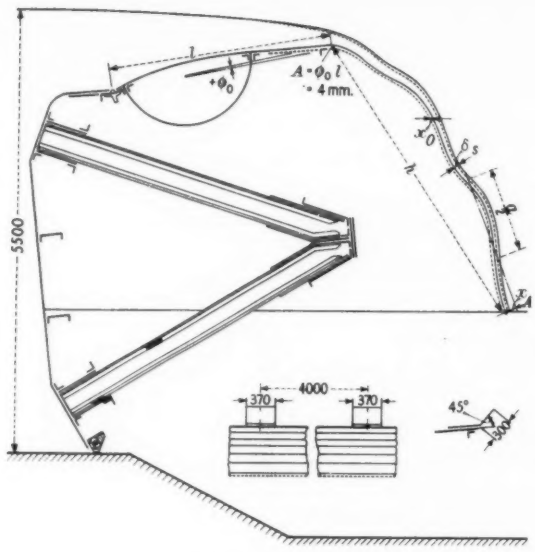


Fig. 15. Overshot flap gate

below the flap and the overshooting water nappe be taken into account. The data covering oscillation of this coupled system are given in section *B*. The water nappe in its entirety performs a small oscillating movement in the horizontal direction which is superimposed on the undulation due to the local pressure distribution. This movement of the water nappe induces vibration in the air space outside the weir and even causes vibration of doors and windows at a considerable distance from the weir. These pressures were measured with two loop galvanometers for a model flap 0·6 m. below the falling water nappe and at distances of 0·2 m. and 2 m. from the weir (Fig. 14). The pressure pulses reach a maximum when the air breaks through due to the very thin jet.

From the equations for the coupled systems we obtain:—

$$\Sigma M = J\frac{d^2\phi}{dt^2} + W\frac{d\phi}{dt} + c_1\phi - \eta_K c_2 x - c_3\frac{d\phi}{dt} = 0$$

$$\text{or: } \frac{d^2\phi}{dt^2} + (10-38)\frac{d\phi}{dt} + 2{,}800\,\phi - \eta_K\, 134{,}000\, x = 0.$$

$$\Sigma P = d_3\frac{d\phi}{dt} - \eta_K d_2\phi + m\frac{d_2x}{dt^2} + \sigma\frac{dx}{dt} + d_1x = 0$$

$$\text{or: } 23\frac{d\phi}{dt} - \eta_K\, 1{,}650\,\phi + \frac{d^2x}{dt^2} + 9\frac{dx}{dt} + 88{,}000\,x = 0.$$

The solution is obtained through the terms $\phi = \phi_o e^{\lambda t}$ and $x = x_o e^{\lambda t}$ where the complex number $\lambda = \delta + i\omega$ is the exponent of the e function.

$$\phi_o(\lambda^2 - 28\lambda + 2{,}800) - x_o(134{,}000\,\eta_K) = 0$$
$$\phi_o(23\lambda - 1{,}650\,\eta_K) + x_o(\lambda^2 + 9\lambda + 88{,}000) = 0.$$

From this system of differential equations with the coupling factor $\eta_K = 0{\cdot}6$ is derived a 4th degree equation for

$$\lambda: \lambda^4 - 19\lambda^3 + 90{,}500\lambda^2 - 595{,}000\lambda + 168{,}000{,}000 = 0.$$

The 4th degree equation can be broken down into two 2nd degree equations as follows:

$$(\lambda^2 - 12{\cdot}52\lambda + 88{,}500) \times (\lambda^2 - 6{\cdot}48\lambda + 1{,}900) = 0$$

in which the negative value of the λ term indicates induced vibration.

The computed frequencies are $n_1 = 6{\cdot}9$ (s^{-1}) and $n^2 = 47$ (s^{-1}) as compared to $n_1 = 6{\cdot}9$ (s^{-1}) and $n_2 = 48$ (s^{-1}) obtained from the oscillograms. In addition to the tailwater level and natural frequency of the flap, the damping of the falling water nappe on the sides of the glass flume will determine whether vibration is induced or the disturbance will decay. Moreover, the frequency n_1 depends to a considerable extent on the coupling factor η_K. If η_K roughly equals unity, the low-frequency oscillation n_1 is well damped. However, if η_K is small, say 0·3, then the frequency of induced vibration $n_1 = 8$ (s^{-1}) cycles, whereas it decreases to $n_1 = 6$ (s^{-1}) cycles with a higher degree of coupling. Slight changes in aeration, splitting of the water nappe or damping, therefore, may well result in a change of frequency from $n_1 = 6$ (s^{-1}) to $n_1 = 8$ (s^{-1}) without changing the elasticity, mass and thickness of the water nappe flowing over the flap.

The free-oscillation frequency with split water nappe was $n_1 = 8{\cdot}5$ (s^{-1}). Since this oscillation controls the volume and pressure change below the weir, it should have been the regime frequency. However, measurements showed a frequency of 6·9 (s^{-1}), indicating that the coupling of the two oscillating systems must be considered. As the model flaps shown in Fig.

Fig. 16. Oscillogram of flap motion and variation in air pressure under the flap gate in Fig. 15

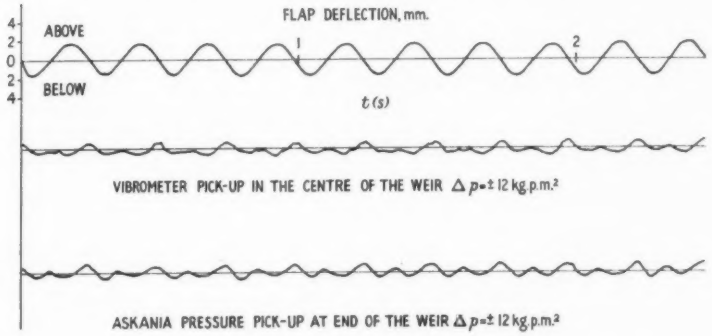
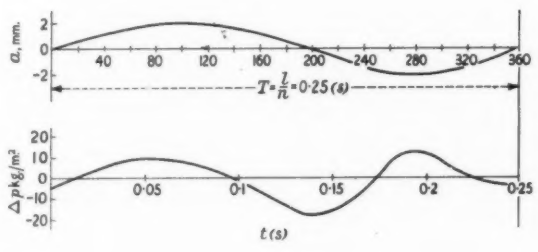

FLAP DEFLECTION, mm.
ABOVE
BELOW
t (s)
VIBROMETER PICK-UP IN THE CENTRE OF THE WEIR Δ p = ± 12 kg p.m.²
ASKANIA PRESSURE PICK-UP AT END OF THE WEIR Δ p = ± 12 kg p.m.²

Fig. 17. Harmonics of pressure vibration under the weir (Fig. 15). $\Delta p = 6{\cdot}6 \cos \omega t - 6{\cdot}6 \cos 2\omega t$ (kg.m.²)



12 were very moderately damped and vibration was instantly eliminated by the use of a slightly higher degree of damping, and more intense damping failed to produce the same effect in full-scale weirs, it was decided to conduct the same tests on a weir of 30 m. span and 2·8 m. head.

The data taken on the weir were the motion of the flap, the variation in air pressure below the weir in the middle (vibrometer pressure pick-up) and at the end (Askania pressure pick-up) (Fig. 16). The pressure change recorded with the Askania oscillograph shows a well-defined harmonic $\Delta p = 6{\cdot}6 \cos \omega t - 6{\cdot}6 \cos 2\omega t$ which was determined by harmonic analysis (Fig. 17). There was no splitting of the nappe by the eruption of air. The harmonic at double the frequency is probably due to the fact that the undulated jet entrains more air than does a jet entering the tailwater at exactly 90°. Penetration of an undulating jet into the tailwater would thus cause a variation in air pressure with doubled frequency.

The air pressures measured in the middle and at the end of the weir were practically identical, thus justifying the assumption that we are dealing with an essentially two-dimensional problem.

In overshot weirs which are entirely open and aerated at the sides, the pressure variation below the weir causes additional three-dimensional oscillation of the air column which may affect the frequency and commencement of vibration to a minor extent as far as coupling, phase shift and damping are concerned. However, this three-dimensional effect is not important from the viewpoint of theoretical study of the overall problem, which can be viewed as a two-dimensional oscillation pattern.

The differential equations from the sum of moments about the pivotal point of the flap and the forces acting horizontally on the water nappe were formed in the same manner as for the plate-flap model.

Oscillation data of the flap gate (Fig. 15)

$\phi = \phi_o \sin \omega t$.

Angle of flap rotation.

$\phi_o = \frac{a}{l} = \frac{2}{2200} = 0{\cdot}0009$.

Measured maximum flap deflection.

$\frac{d\phi}{dt} = \phi_o \omega \cos \omega t$.

Flap velocity.

$\frac{d^2\phi}{dt^2} = -\phi_o \omega^2 \sin \omega t$.

Flap acceleration.

$\omega = 25{\cdot}1$ (s^{-1}).

Cyclic frequency of flap.

$n_o = 4{\cdot}0$ (s^{-1}).

Flap frequency.

$J_1 = m_1 r^2 = 2{\cdot}5$ (m.t.s.²).

Moment of inertia of the mass about the pivotal point.

$J_2 = \text{approx.} \frac{m_1 \times l^2}{12} = \text{approx. } 0{\cdot}6$ (m.t.s.²).

$m = G/_g = \frac{17}{9{\cdot}81} = 1{\cdot}73$ (t.m. $^{-1}$ s²).

$J_3 = 0{\cdot}3$ (m.t.s.²).

Chain component.

$J_4 = 2{\cdot}0$ (m.t.s.²).

Water mass participating in oscillation.

$J_K = 5{\cdot}4$ (m.t.s.²).

Total moment of inertia.

The moment of inertia obtained by computation, J_K, was less than that determined by the test (J_V).

$J_V = \frac{c}{\omega^2} = 6{\cdot}3$ (m.t.s.²).

Moment of inertia from the oscillation recording.

$M_1 = -J_V \frac{d^2\phi}{dt^2}$ (m.t.).

Moment set up by mass forces.

$w = \frac{\delta \omega J}{\pi} = \frac{0{\cdot}4 \times 25{\cdot}1 \times 6{\cdot}3}{3{\cdot}14}$

Damping.

$\delta = ln\ 1{\cdot}5 = 0{\cdot}4$.

$M_2 = -w \frac{d\phi}{dt}$ (m.t.).

Damping moment.

$M_3 = -c\,\phi = -3{,}950\,\phi$ (m.t.).

Elastic restoring moment determined by a test on the weir.

$s = 30$ (m.).

Clear width of weir.

$l = 2{\cdot}2$ (m.).

Length of flap from pivoted point to water overfall edge.

$h = 3{\cdot}5$ (m.).

Distance between overshot flap end and tailwater.

$F = s\,h = 30 \times 3{\cdot}05$.

$F = 91{\cdot}5$ (m.²).

Area of water nappe overshooting the weir.

$V_m = s\,h\,b = 91{\cdot}5 \times 7{\cdot}3$.

$V_m = 670$ (m.³).

Air volume under the jet when the latter is in zero position, *i.e.* when it is not oscillating.

$p_m = 10{,}000$ (kg. m.$^{-2}$).

Mean pressure below jet.

$n = 1{\cdot}1$.

Exponent under conditions of polytropic compression.

$M_5 = c_2 x = x \frac{l^2\, s\, p_m\, n\, F}{2\, V_m}$

$M_5 = 108\, x$.

Moment acting on the flap set up by a movement of the water nappe in the x direction.

$\Delta p = 6{\cdot}6 \cos \omega t - 6{\cdot}6 \cos 2\ \omega t$.

Air pressure below the weir solved by means of a Fourier analysis. Theoretical determination as a first approximation based on the first term 6·6 cos ωt.

$M_6 = \Delta p \frac{l^2}{2} s \cos \omega t$.

Moment due to change in volume.

$M_4 = 0{\cdot}48 \cos \omega t$ (m.t.).

To the undulating water nappe flowing into the tailwater.

$M_4 = \frac{0{\cdot}48}{\omega\, \phi_o} \phi = 21{\cdot}3\, \phi$.

M_4 is in phase with the flap velocity.

$m = \frac{\delta_s F \gamma_w}{g} = \frac{0{\cdot}025 \times 91{\cdot}5}{9{\cdot}81} = 0{\cdot}23$.

Mass of jet.

$w = \frac{m \delta v}{\pi} = \frac{0{\cdot}23 \times 0{\cdot}69 \times 24{\cdot}4}{3{\cdot}14} = 1{\cdot}25$.

Damping of jet $\delta = 0.69$.

$$P_3 = -d_1 x = -\frac{F^2 p_m n}{v_m} x = -138\,x.$$

Elastic restoring force due to compression of air.

$$P_4 = \frac{\phi l^2 s p_m n F}{2 v_m} = 110\,\phi.$$

Influence of flap rotation ϕ on air pressure below the weir.

$$P_5 = -\Delta p\, F \cos \omega t.$$

$$P_5 = -\frac{6{\cdot}6 \times 30 \times 3{\cdot}05}{0{\cdot}0009\ \ 25{\cdot}1}\phi.$$

$$P_5 = -27{\cdot}1\,\phi.$$

Oscillation-inducing force due to undulation of water nappe overshooting the weir.

$$\phi - 0{\cdot}2\,\phi + 630\,\phi - 17x = 0.$$

$$116\,\phi - 470\,\phi + \ddot{x} + 5{\cdot}4x + 600x = 0.$$

The corresponding system of equations for determination of the complex exponent becomes

$$\begin{bmatrix} \lambda^2 - 0{\cdot}2\lambda + 630 & -17 \\ 116\lambda - 470 & +\lambda^2 + 5{\cdot}4\lambda + 600 \end{bmatrix} = 0.$$

$$\lambda^4 + 5{\cdot}2\lambda^3 + 1{,}229\lambda^2 + 5{,}250\lambda + 370{,}000 = 0.$$

$$R = 5{\cdot}2 \times 1{,}229 \times 5{,}250 - 5{,}250^2 - 5{\cdot}2^2 \times 3{\cdot}7 \times 10^5 < 0.$$

Hence the computation, in conformity with the test results, shows that induced vibration is to be expected.

Breakdown of the 4th degree equation into two quadratic equations results in

$$(\lambda^2 + 9\lambda + 475)\ (\lambda^2 - 3{\cdot}8\lambda + 780) = 0.$$

The negative sign of the λ member in the second term in parantheses indicates induced vibration at a frequency of

$$\omega = \sqrt{780 + \left(\frac{3{\cdot}8}{2}\right)^2} \text{ or } n = 4{\cdot}4\ (s^{-1}).$$

The measured frequency was $n = 4{\cdot}0$; the slight difference may be attributable to inaccuracy in the assessment of damping and coupling.

Fig. 18. Effect of flow splitters on overshot flap

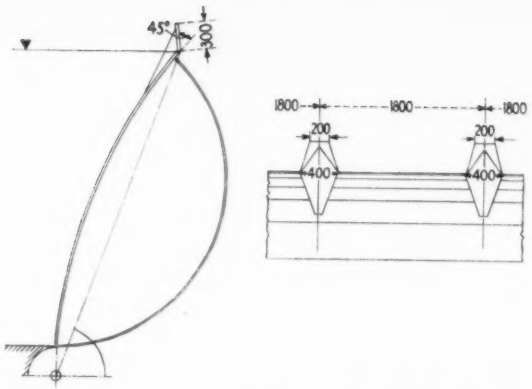


Fig. 19. Arrangement of jet-dissipating devices

If the peak value of air pressure variation below the weir, $\Delta p = 6{\cdot}6$ kg. m^2, remains low, no vibration in other phase positions will occur under the existing damping and coupling conditions.

If the amount of undulation, and hence the pressure difference Δp, increases slightly due to lowering of the tailwater level, vibration of a somewhat different frequency will occur. A particularly critical range from the viewpoint of vibration is the one in which the peak value of pressure fluctuation is in opposition to the damping, i.e. when the vector of the moment set up by the pressure due to undulation coincides with the flap velocity vector.

The marked undulation is caused by the velocity pulse imparted to the overshooting water when the flap passes through its zero position and also by the building up of pressure on the gently undulated nappe. This pressure considerably increases the amount of undulation in the lower part of the nappe, where the thickness of the jet has diminished, and thereby intensifies the volume and pressure fluctuation below the weir. Flow spoilers (Figs. 18, 19) have given satisfactory results as a means of eliminating such vibration. Due to the splitting of the jet, the elasticity expressed in the 2nd differential equation is eliminated. Moreover, if the spoilers are close enough to each other (say 2 m.) the pressure differential on the falling undulating water nappe cannot sufficiently develop and the residual slight pressure differential is not transmitted to the flap with the same intensity as would occur in an enclosed air space. If the water nappe overshooting the flap is too high to be split by the spoilers (as they must be kept low because of ice), it is important that the spoilers should impart to a sufficiently large quantity of overshooting water a phase shift of about 180° in relation to the normal overfall. The undulations in these two portions of water will act in opposite directions, thereby preventing vibration even though the nappe is not split.

Overshot Rigid Weir Crests

In the weir oscillation phenomena described in the preceding section the movable flap is an essential controlling and amplifying element.

However, vibration is also observed in weirs with a masonry overfall edge. A particularly well-known case is that of the Upper Weir at Hameln, where the phenomenon is referred to as "weir flutter." The air vibration caused by the falling water induces vibra-

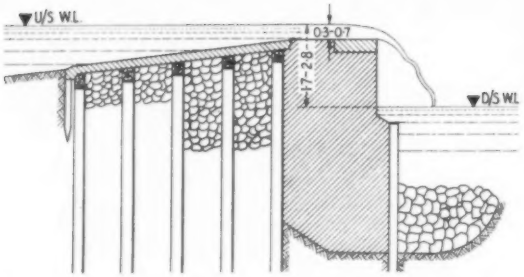


Fig. 20. Section through crown of Upper Weir at Hameln

tion in doors and windows in the vicinity with resultant noise disturbance (Fig. 20).

As this is a concrete-built weir without a movable flap and the subsoil does not respond to the oscillation characteristics and initial undulation of the overshooting water nappe, $\Sigma M=0$, is voided and the coupling member "P_1" in the term $\Sigma P=0$ is negligible. The equation is reduced to a simplified form $\Sigma P=0$, in which the x-direction can be assumed, by approximation, to be normal to the water nappe.

$$m\,\frac{d^2x}{dt^2}+\sigma\frac{dx}{dt}+d_1x=\Delta p\,F\sin(\omega t+\beta).$$

In the case of resonance, when the peak value ΔP is in opposition to the damping σ as a result of a phase shift caused by the tailwater level, a slight difference in pressure or slight change of volume of the air under the weir is sufficient to maintain continuous vibration. Under conditions of certain tailwater levels, the pressure fluctuation causes slight undulation of the jet overshooting the weir edge. The pressure differential occurring on the falling water nappe amplifies the undulation and the curved nappe, on entering the tailwater, causes variations in volume which entail pressure fluctuation. The latter, by retrogression, causes the initial undulation at the overfall edge. The frequency is determined by the thickness of the jet and the air volume, being

$$n=\frac{1}{2\pi}\sqrt{\frac{d^1}{m}}=\text{approx. 3 to 5 } (s^{-1}),$$

and the wave length is $a=\frac{v}{n}=0{\cdot}5$ m. to 2·0 m. depending on velocity, head and tailwater level. As a result, 2 to 4 undulations depending on the head will be seen, moving downward at the speed of free fall. Weirs of this type of construction, characterised by a rigid overfall edge, have a limited vibration range and the means employed to eliminate vibration need not be as effective as in the case of weirs with elastic flaps. In the case of flap weirs made of steel, and for the most part suspended from elastic chains or cables, the movable flap is the vibration-controlling agent. Due to the uniform initial undulation extending over the whole of the clear width, the volume and pressure variation is more uniformly excited than in weirs with a rigid overfall crest. More effective action for elimination of vibration, therefore, is required than with rigid types of construction. However, it has been shown in practice that, whatever the degree of elasticity, vibration can be safely eliminated by the use of appropriate flow spoilers.

(To be continued.)

Correspondence

Turbulence and Eddy Formation

To the Editor of WATER POWER,

Dr. Jaeger's review of the two papers recently published by the Hydraulic Research Laboratory of the Berlin Institute of Technology brings into focus our very imperfect knowledge of the mechanism of turbulence and eddy formation around hydraulic structures.

The need for reseach in this subject has always been recognised, and the recent publication in the Proceedings of the American Society of Civil Engineers of four papers on this subject has shown that a start has been made on quantitative measurements. However, the American researches have all been directed to the development of satisfactory turbulence meters which express turbulence in the mathematical symbols of Navier-Stokes and Prandtl, which, to the practising engineer, lack physical significance. Dr. Jaeger's approach on the basis of momentum flux or total force is easier to understand and allows simpler laboratory instrumentation. If, as the Berlin researches suggest, Dr. Jaeger's generalised equation of flow holds good in turbulent flow, it opens up a tremendous avenue for further researches.

The review also brings forward the point that a great number of practical measurements have to be done to supplement the theoretical treatments referred to above. In particular, we would like to point out that researches on structural vibrations due to turbulence have not, to our knowledge, been included in any of the programmes of research put forward by the various hydraulic institutes. Work on this subject was started by von Karman who showed how the vortex trail behind a stationary cylinder could cause forced vibrations of the cylinder and possibly its ultimate failure from fatigue. Two recent papers presented to the Seventh Congress of the IAHR last year showed that the same phenomenon occurs around the trash racks of hydraulic intakes.

In addition to vibrations having their seat at racks or pillars, various hydro-electric power companies have experienced severe vibrations in their pipelines which may be due to turbulence in manifolds and at junctions. It is, therefore, of importance that the subject of structural vibrations due to turbulence be given intensive study.

The firm with which we are associated, H. G. Acres & Company Limited, has already made some laboratory measurements of the frequency and magnitude of oscillations caused by turbulent flow and plans to extend this programme of research. We would like to know if there are any other individuals or organisations prepared to participate in this work.

C. N. SIMPSON, Chief Engineer, Hydraulic Division

I. W. MCCAIG, Hydraulic Engineer

H. G. Acres & Co. Ltd., Niagara Falls, Canada.

The International Union of Geodesy and Geophysics

Papers on statistical theory and methods in hydrology and on some hydrological idealisations are discussed in this further report on the meeting of the International Association of Scientific Hydrology, held in Toronto in September, 1957

PART TWO

THE study on "The Relation Between Monthly Precipitation and Monthly Run-off," by Dionis Strebenovic, of Yugoslavia, provides a link between the empirical treatments of hydrometric data discussed in Part One of this series of articles and the statistical papers described below. The purpose of this study, as that of M. S. Sachs, is to enable the hydropower engineer to make the optimum use of his water resources, in this case by establishing for his area an empirical equation linking monthly run-off to the amounts of rain falling both during the current and the preceding months. He uses the method of least squares to find a coefficient and an index in his equation which, by application to the discharges of the great Iraqi rivers as well as those of the Sava and the Drava in Yugoslavia, he has shown to be of practical value.

Professor J. Lambor, of Warsaw, in "The Evaluation of the Run-off Coefficient as Applied to Hydrological Forecasts," starts from the "losses" (the differences between rainfall and run-off) rather than the ratio of run-off to precipitation, and divides the losses into one part which is a function of the "retentive capacity" of the catchment and another part which, depending on deep percolation, etc., is also a function of the duration of the rain. In his equation for the "run-off coefficient," two coefficients and three exponents have to be found by such methods as that of least squares, as was the case with the equation of Strebenovic. Not only was Lambor's equation shown, in the discussion, to be capable of giving precise information on the "run-off coefficient," but its coefficients seem capable of being developed into indices of the hydrological behaviour of various catchments.

In a second paper on "A Probability Function Including Regional Parameters" Professor Lambor discusses the usefulness of certain skew distribution functions in the description of hydrological phenomena. With the same aim as T. Dalrymple, but by a different approach, he arrives at mathematical expressions which, he claims, describe the full range of variation, for example, of floods more accurately than the functions used up to now. The new formulae are exponential and power functions, with dimensions and characteristics of the various catchments allowed for by three coefficients which will also vary according to the region under consideration. The results are plotted on a series of maps from which it is possible to read off the values of coefficients which, substituted in the new formulae, are claimed to give the magnitudes of flood and drought flows to be expected with any required frequency on any catchment under study.

The engineer is often faced with the problem of forecasting long-period averages of run-off from a short series of observations, and many studies of methods used in such cases have been published. Monsieur A. Coutagne discusses the problem in another statistical paper, "How Is the Periodic Variability of a Hydrological Factor to be Characterised." It is clearly impossible to find an exact long-term mean value on the basis of a short series of records, but he has attempted to indicate the range of errors to which mean values derived from series of various lengths may be expected to be subject. For the case when run-off records are far too short, he adds a useful note on rainfall/run-off correlations which may increase the degree of the engineer's confidence in the computed mean run-off figure.

The construction of the first nuclear power station of Electricité de France on the Loire, just upstream of the mouth of the Vienne, gave rise to an extensive and thorough hydrological study on which Monsieur J. Jacquet submitted a report. The total catchment area of 80,000 sq. km. (say 30,000 sq. miles) is meteorologically and hydrologically far from homogeneous, and various analytical and statistical processes have been tested against the observations of floods and droughts made near the site of the station.

"The Determination of Flood Frequencies in a Major Drainage Basin," by H. E. Schwarz of the U.S. Corps of Engineers, is an account of the mathematical frequency analyses developed to deal, once again, with the problem of a river of which too few reliable records are available. By correlating the records from various stations and by studying the influence of various catchment characteristics, the author develops frequency curves which are claimed to possess much greater accuracy than those computed from the data from a single station, and which enable him to give an indication of flood frequencies even at a section of the main river or of a tributary which has not been gauged at all.

Two papers on the statistical theory of extremes were submitted by Z. Kaczmarek, of Warsaw. "A Method of Determining the Frequency of Droughts" and "Efficiency of the Estimation of Floods with a

Given Return Period." Both are able contributions, but—like most other statistical papers in this field—leave on one side the question of statistical homogeneity which was raised in these columns before* and seems to remain the crux of the problem of extrapolation of flood and drought figures from relatively short records.

Professor Maurice Pardé, of Grenoble, who is well known for his encyclopaedic knowledge of hydrometric data, discusses in a paper on "Drought Flows in Rivers" (in terms of "specific discharge" or run-off per unit area of catchment) the low discharges observed in rivers in France and in many overseas areas, and finds convincing explanations for some of his extremes by referring to surface storage, geology and climate. His geographical approach will, presumably, lead to the production of world-wide water-resources maps which will provide the engineer with a first indication of the basins worthy of special investigation.

Another use of high-speed computers is described by D. Tonini, of Italy, in "Experimental Forecasts of River Discharges." If run-off is correlated with all the characteristics of a river and its catchment area as well as all the relevant preceding meteorological observations, the computations become too vast to be handled manually. High-speed automatic computing engines, however, will quickly digest a vast amount of data fed into them in the form of perforated tape or cards and provide an answer of practical accuracy.

Unit-hydrograph theory has, by some of its advocates, been endowed with a mystique which may be somewhat repugnant to practical engineers. The view seems to be gaining ground, however, that—in skilled hands—unit hydrographs are a useful engineering tool, based on the theoretically unobjectionable principle of mechanical similarity and leading to answers with practically tolerable errors. As a unit-hydrograph analysis yields not only the peak value of a flood, but its whole life history, J. Larrieu, of France, in "The Evaluation of Catastrophic Floods by the Method of Synthetic Hydrographs," uses it as a basis for further developments which include the use of statistical ideas. By starting from observed severe floods from a catchment and allowing for catastrophic precipitation on a catchment with a temporarily very high run-off coefficient, the author arrives at hydrographs of direct usefulness to the designer of a dam and spillway.

J. E. Nash, of the (British) Hydraulics Research Organisation, in "the Form of the Instantaneous Unit Hydrograph," seems to fill a gap—deplored by Larrieu and others—by providing us with a method of deriving a unit hydrograph from a complex flood record.

Conclusion

The general water-development projects often associated with hydro-power schemes demand a knowledge of most of the other topics touched upon in the remaining contributions on surface-water hydrology as well as on other hydrological subjects. Some of the papers on topics outside the field of surface water, however, arose out of hydro-electric practice and deserve special mention. An example is D. Tonini's "New Research into the Relation Between Snow Cover and River Flow" which was the result of the need for a method of forecasting the quantity of water available in the hydro-electric reservoirs in the Eastern Alps, and again leads to empirical correlation equations.

A report on the "Glacier Variation and Trends in Run-off in the Canadian Cordillera," by E. P. Collier, describes the effect, on the run-off of glacier-fed streams, of changes in climate which cause glaciers to grow or to recede. In some areas, a reversal in the trend of glacier growth may profoundly affect the quantity of water available annually for power production and other purposes.

A large group of papers deals with land erosion and its causes, and is of interest to engineers concerned with rivers which carry a heavy bed load and much suspended sediment, and with reservoirs fed by such rivers.

Another group, on precipitation measurement and analysis, includes a paper by L. Serra, of France, on "Improving Precipitation Measurement," which gives useful information on the sources and on the magnitude of errors in precipitation measurements and will be of especial interest to those engineers who, perhaps by lack of run-off data, are compelled to estimate their water resources from rainfall measurements.

Instruments were discussed, with particular reference to rationalisation, but there were some reports on special developments, one of them by M. J. Goldschmidt, of Israel, who had designed and tested a water-level recorder which could be left in position, without attention, for up to six months. Where preliminary investigations are to be undertaken in inaccessible parts of the world, such special equipment would clearly be of great value.

The next General Assembly of the International Union and its constituent Associations is to take place in Helsinki, Finland, in the summer of 1960, when the I.A.H. hopes to continue its discussion of the subjects covered so far and to add a symposium on the problems of tidal rivers and estuaries. .

The Toronto proceedings of the International Association of Scientific Hydrology will shortly be available for purchase from the Secretary-General, Professor L. J. Tison, of 61 rue des Ronces, Gentbrugge, Belgium.†

Water Control Gate Equipment. A pamphlet received from The Armfield Hydraulic Engineering Co. Ltd. gives illustrated particulars of the various types of water-control gates they manufacture. These include simple river and irrigation hatches, free roller and fixed roller gates, tilting and radial gates, stoplogs and hoists, fish-pass gates, and electrically or hydraulically operated gates.

Computing Stresses in Pipe Systems. Ferranti Limited have sent us a copy of a leaflet (DC.27/24) which gives a brief description of the Ferranti Pegasus Computer for the computation of stresses in three-dimensional, multi-anchor pipe systems. It may be used for steam or hydraulic pipe layouts. The method of pipe stress analysis developed by Mr. H. M. Gemmell, of Yarrow & Co. Ltd., is used and is adapted for automatic computation. Further details are available on request to Computing Service, Ferranti Limited.

* Correspondence, WATER POWER, Vol. 9, No. 7, July 1957, p. 264.

† Also obtainable through H. K. Lewis & Co., of London.

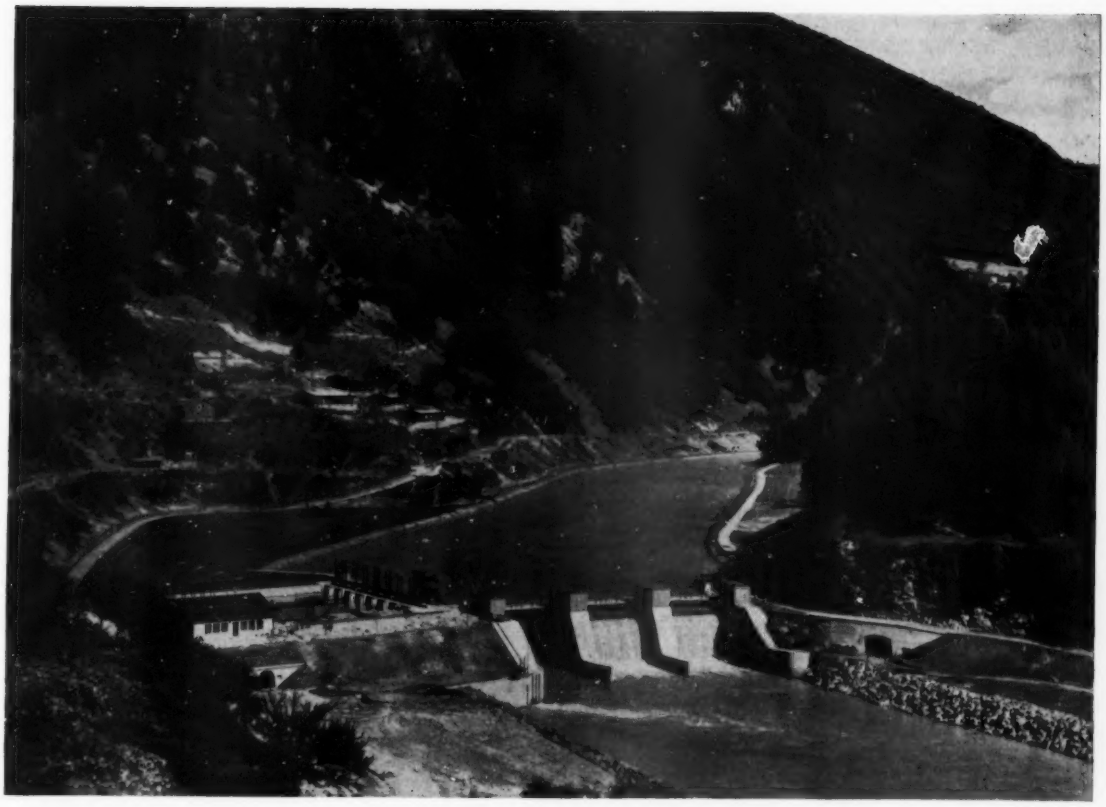


Fig. 1. View of Runserau intake

The Prutz-Imst Underground Power Station

Dr. E. Königshofer describes a recently completed underground power plant built by Tiroler Wasserkraftwerke Aktiengesellschaft (TIWAG), Innsbruck, on the river Inn, near Landeck

THE river Inn, a tributary of the Danube, forms the border between Austria and Germany in the lower part of its course. The catchment area also includes Swiss and Italian territory so that its utilisation is of interest to four countries.

In Austria the Prutz-Imst power station, with an installed capacity of 87,000 kW and a power output of 451 million kWh per year, was recently completed by the Tiroler Wasserkraftwerke A.G. (TIWAG), Innsbruck. This plant is of special interest as it was constructed as an underground station.

As shown in Fig. 2, it is situated on the bend of the Inn by the city of Landeck. The length of the pressure tunnel is 12·3 km., about half the length of river bed bypassed. The head thus obtained varies between 138 m. and 145 m. Just below the plant the Pitz rivulet flows into the Inn, but the flow has been diverted back into the power scheme by means of a lateral tunnel. The plant has been designed on a utilisable water flow of 75 cu. m. per sec.

The major parts of the plant are the water intake at Runserau, the pressure tunnel, the lateral tunnel at Wenns in the Pitz valley, the surge tank, the pressure shaft and the underground power station.

The water intake, Fig. 1, is at an elevation of 850 m. above sea level and comprises a weir having three

openings, a trashrack, and desilting arrangements. The three openings (with a free width of 13 m. each and a gate height of 10 m.) are equipped with hooked twin gates which can be operated either manually or electrically; they can also be automatically controlled. The trashrack is cleaned by a raking device which tips the trash into a scavenging duct whence it is swilled by the discharge from a 28 kW electrically driven pump. The desilter possesses 17 valves which can be operated individually either by hand or electrically.

The pressure tunnel, Fig. 6, cuts across a mountain at an elevation of 1,700 m. and has a diameter of 5·1 m. from the intake at Runserau until it joins the lateral tunnel from Wenns; from this point the diameter is 5·3 m. to the pressure shaft. It is circular in section slightly flattened at the base, this shape being considered as best satisfying the hydraulic and static requirements. It is concrete lined throughout, the thickness varying with the conditions of the rock and the depth of covering.

From the Pitz intake the water is conveyed through a concealed reinforced-concrete pipe, 1·55 km. in length, to the entrance of the lateral tunnel.

The surge tank above the pressure section is of the differential type and is designed for complete shutdown and for sudden load increments from half to full load. The water volume in the pressure section, 350,000 cu. m., required especially large dimensions for the tanks, and two shafts are provided 50 m. high and having a diameter of 6 m. for the lower portion and 12 m. above.

The pressure shaft to the generating station is 4·4 m. in diameter and 140 m. long, and is steel lined

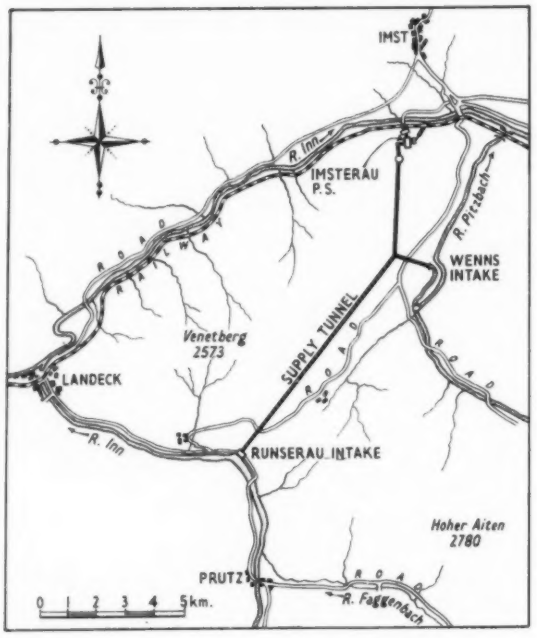


Fig. 2. Map of the Prutz-Imst development

Fig. 3. View in the power house at turbine level, showing the inlet valves

throughout, the plate thickness ranging from 10 to 16 mm.

The rock chamber for accommodating the generating units and the other electrical equipment has an egg-shaped cross-section, Fig. 4, and is 56 m. long, 20 m. wide and 26 m. high. The machine hall proper has reinforced-concrete walls up to the crane runways and an arched false ceiling. The outer interspaces accommodate the busbars and are used as air ducts. Air conditioning of the chamber is effected by mixing a variable amount of fresh air with warm air from the generators and then conveying the mixture to the main hall and ancillary compartments. Any water collected in the sump is removed by three pumping units.

Three vertical generating units have been installed, each consisting of a Francis turbine, having a speed

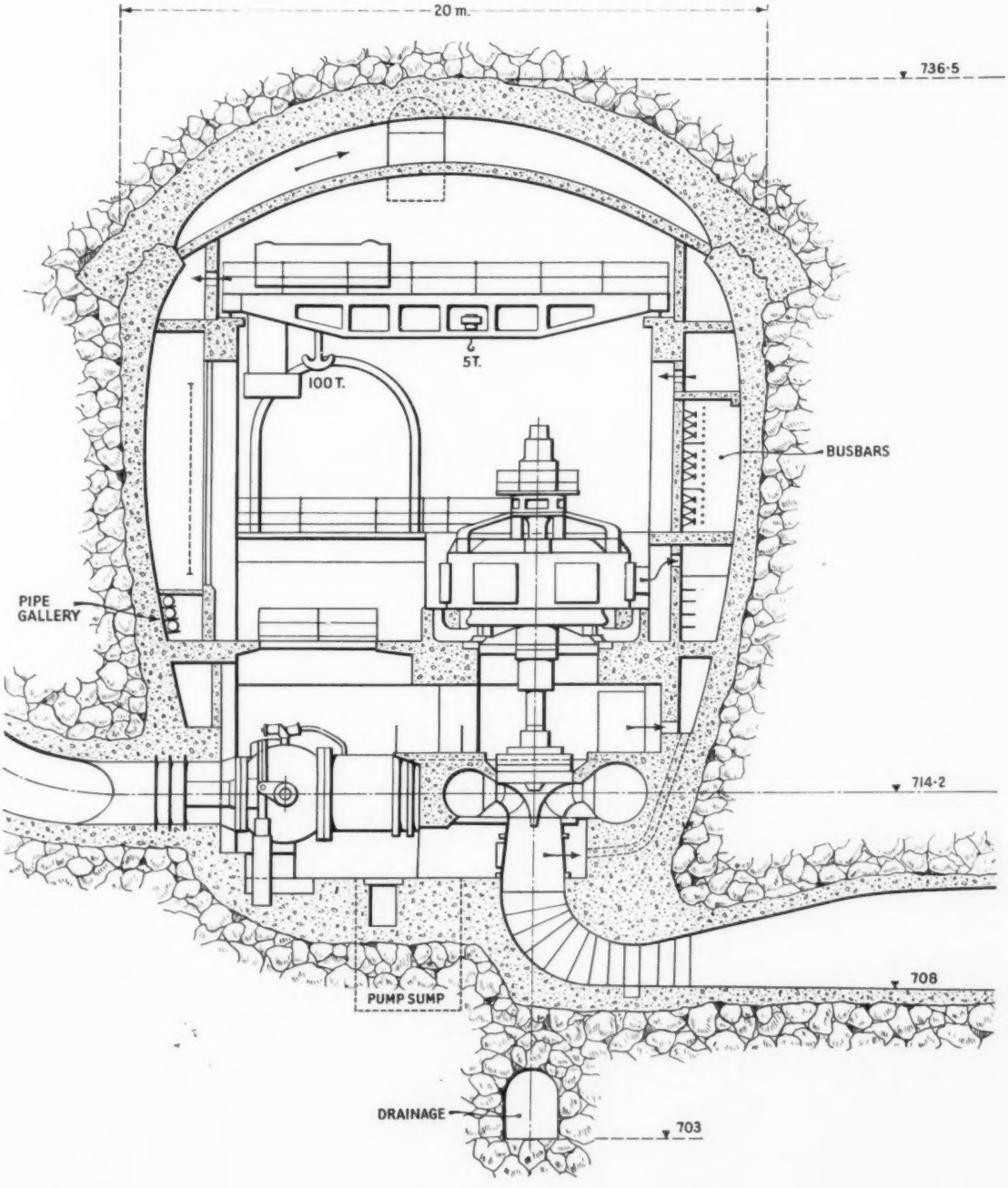


Fig. 4. Sectional elevation of the power house

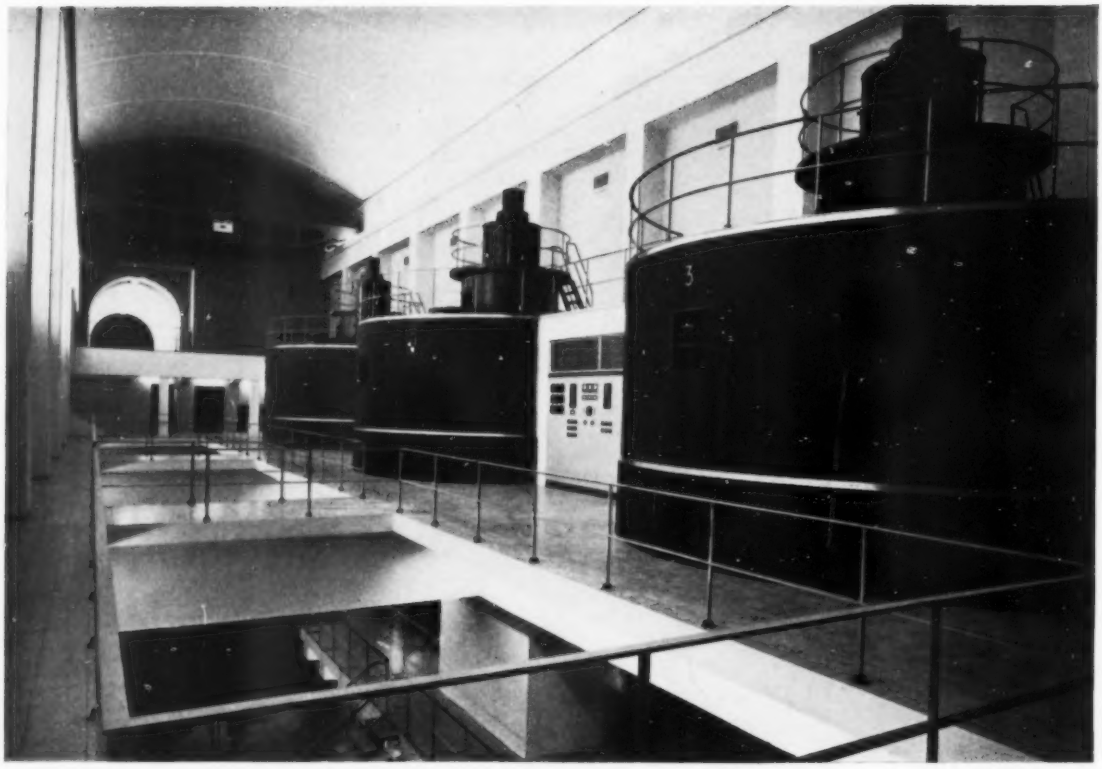


Fig. 5. View in machine hall at generator-floor level

of 375 r.p.m. and operating at a head of 121·7 to 142 m., passing 25 to 27·2 cu. m. per sec., giving an output of 36,000 to 46,000 h.p. The generators are three-phase, 10,500 V, 40,000 kVA machines with closed-circuit cooling, Fig. 5. Each generator is connected permanently to a transformer of 40,000 kVA capacity. The transformers have been installed outdoors and step up from 10,500 V to 124,000 V. For the time being four overhead transmission lines lead off from the outdoor substation. An administrative building accommodates the offices, the control room, the cable basement, an assembly hall and a workshop. In addition there is an auxiliary transformer station for the supply of incoming energy for internal power requirements. An auxiliary generating unit is installed in the power house to ensure this essential energy should the external supply be interrupted.

Of the total power produced, 451 million kWh, 31% is generated in the six winter months and 69% in the summer months.

The following is a list of the principal contractors:—

Spillway Gates, Stoplog Crane
VOEST, Linz.

Pressure-Shaft and Surge-Tank Linings, Surge-Tank Valves
Waagner Biró A.G., Graz.

Turbines and Globe Valves
Escher Wyss Ltd., Zürich.

Generators, Water-Intake Electrical Equipment
Siemens-Schuckertwerke, A.G., Wien-Erlangen.

Transformers, Outdoor Switchgear
ELIN, A.G., Wien.

Control Room, Cable Basement
Neue Österreichische Brown Boveri, A.G., Wien.

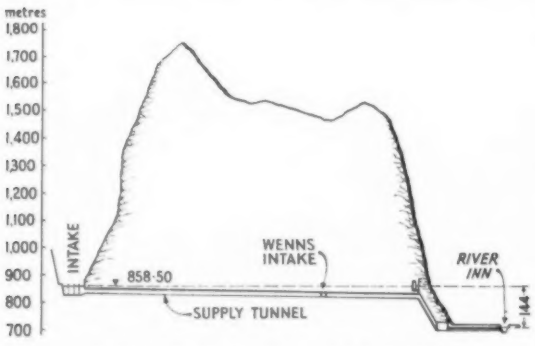


Fig. 6. Profile of the supply tunnel

Civil-Engineering Contracting. A well-produced brochure issued by The Federation of Civil Engineering Contractors explains the structure of the industry, what it achieves, and the opportunity it offers to new entrants who are attracted to an enginering career. We believe it to be the first comprehensive review ever to be published in this country of the opportunities open to young people in the civil-engineering contracting industry, and over 9,000 copies are being sent to schools, technical colleges, universities and Youth Employment Offices.

Book Reviews

Hydro-Electric Engineering Practice. Edited by J. Guthrie Brown, assisted by 25 specialist contributors. Blackie & Son Limited, 17 Stanhope Street, Glasgow. Volume I, "Civil Engineering." 1,220 pp., 720 ff. £9 9s. net; Volume II, "Mechanical and Electrical Engineering." Co-ordinating editor, P. L. Blackstone. 770 pp., 360 ff. £6 6s. net; Volume III, "Economics, Operation and Maintenance." Co-ordinating editor, J. K. Hunter. 500 pp., 120 ff. £4 4s. net.

This three-volume compendium may well come to be regarded as the most important work of reference on hydro-electric engineering practice yet published. The amount of labour that has gone into its preparation must have been stupendous, but the result has been the production of the most comprehensive treatment of the subject that has ever been attempted. Even so, in the interests of space the individual authors have had to exercise the virtues of conciseness and restraint, and certain omissions can be discovered if they are searched for. Nevertheless a careful study of the three volumes—from which we ourselves have benefited in no small measure—has impressed us both with the breadth of vision that has guided its compilation and with the vastness of the subject itself.

The work is significant also because, for the first time for many years, it gives to the world a designer's textbook of British, and to a lesser extent Continental, practice. This might seem presumptuous if the hydro-electric resources of Great Britain only were taken into account, but British designers have built up a wealth of experience overseas, as well as at home, so that a publication of this kind can be fully justified.

If we have any slight criticism of a brilliant piece of work, it is that there appears to be some uncertainty as to how far European practice, as opposed to British, is intended to be covered. Thus, for instance, the chapter on arch dams rightly draws fairly heavily on Continental design procedures and practice, as we would expect from its author, Dr. Jaeger (although Dr. Jaeger has very wisely included an account of the relaxation method of analysis developed at Imperial College, London), but the chapter on steel pipelines makes no mention of the overpressured self-hooped penstocks so popular in France, or indeed of any type of hooped pipe. Similarly, there is no mention of the tubular types of turbine developed on the Continent in recent years for low-head and tidal power. Some such uncertainity, of course, is only to be expected when a work is produced by a group of authors, for the emphasis inevitably changes with the author. What is certain is that this is the most authoritative reference book of British practice that has yet appeared.

We have spoken of the breadth of vision that has guided the compilation of the work. Indeed, we cannot recollect any aspect of hydro-electric practice that is not at least touched upon in the course of the three volumes. Questions of overall planning, and so forth, are treated with unusual thoroughness. This is particularly evident in the third volume, which is almost entirely devoted to subjects that are largely ignored in the ordinary textbook.

As may already have been gathered the compendium has been planned as a practical designer's work of reference. For the most part it leaves standard elementary theory to the normal textbook. It does not set out to be a record of hydraulic research, nor to be a descriptive review of progress in various countries. Many schemes, both in Britain and on the Continent, are referred to and illustrated, but always in connection with some point of design, and it is the engineer actually engaged in the planning, design or operation of hydro-electric schemes or their components who will benefit most from this publication. In this connection the British and Continental preference for dealing with design problems fundamentally rather than empirically is most noticeable and commendable.

With a work of this size it would take us too far to give a detailed summary of the contents or even a complete list of the authors, but the following brief comments should indicate the scope of each volume. Volume I, which is much the largest, is devoted primarily to the civil-engineering side, although other aspects are touched upon, and is divided into three sections. The first, entitled "Preliminary Hydraulic Considerations," deals with rainfall, run-off, hydraulics, and the use of hydraulic models. The second section, "The Planning of the Scheme," goes into questions of overall design and site investigations. Some of the matters considered here are dealt with more fully in one or other of the succeeding volumes, but such duplication as exists is fully justified, as the first volume thereby becomes a self-contained entity. The bulk of the text of this volume, however, is contained in the third section, dealing with "The Design and Construction of Civil Engineering Works," which discusses dams of all kinds, spillways, intakes, outlets, canals, tunnels, surge chambers, pipelines, valves, water hammer, and power stations (both surface and underground). The volume concludes with two unusual but useful chapters on the aesthetics of hydro-electric structures and on fishery requirements.

Volume II, which deals with mechanical and electrical matters, is divided into four sections, covering water turbines, electric generators, control and transmission equipment, and power-station planning. All sections are competently and exhaustively handled, but special note must be taken of the third section, which lays emphasis on features of transformers and switchgear that are special to hydro-electric practice, and includes important chapters on control and communications equipment and on high-voltage transmission. The section on power-station planning is the mechanical and electrical counterpart of the corresponding chapters in the civil-engineering volume. Excellent chapters are included on auxiliary plant and on equipment for pumped-storage schemes, but strangely enough, the Deriaz feathering Francis pump-turbine—a revolutionary British design—is dismissed in seven lines without even being mentioned by name. Appendices include a theoretical discussion of turbine governing and an account of methods of water-flow measurement.

Volume III, in our opinion, does much to place this work in a class by itself, for it deals with subjects that are essential to a balanced appreciation of hydro-electric development but are rarely dealt with in published works. It commences with a review of world power resources and then goes thoroughly into the economics of hydro-electric power, including such

matters as combined hydro and thermal plant, pumped-storage schemes, and multi-purpose projects. Trends in development and design are noted, and load prediction, advance planning and the preparation of reports and estimates are discussed. The remainder of the volume is devoted to management, operation and maintenance. An appendix contains three unusual but valuable chapters on wind power, the medical aspects of reservoir construction and management, and nuclear power.

We have not been surprised to learn that this mighty work took ten years to prepare, but we understand that the text was carefully revised immediately before the books were printed in order to prevent "dating." Even so, we are left with the impression that the work has not fully succeeded in keeping pace with the developments of the last two or three years; but to expect such perfection in a publication of this size would be to ask for the impossible.

The printing, illustrations, paper and binding would be a credit to any book publisher, and worthily match the contents.

Rules Governing the Short-Circuit Testing of Air-Blast Circuit Breakers for Alternating-Current Systems. The Association of Short-Circuit Testing Authorities (Inc.), 36 Kingsway, London W.C.2. Price 10s. net.

These rules have been formulated by ASTA to secure uniformity in the short-circuit testing of air-blast circuit breakers pending the publication of a British standard. Until such a standard has been published the association will issue Certificates of Short-Circuit Rating in the event of the circuit breaker successfully passing the tests prescribed in these rules. The document offers a uniform method of interpreting the results obtained and the assessment of the performance of a circuit breaker.

Kempe's Engineer's Year Book, 1958. Edited by C. E. Prockter, M.I.E.E., M.I.Mech.E., under the direction of B. W. Pendred, M.I.Mech.E., M.I.S.I. Published by Morgan Brothers (Publishers) Limited, 28 Essex Street, Strand, London, W.C.2. Two volumes. 3,000 pp. Illus. Price 82s. 6d. Postage 2s. 6d.

This admirable year book, now in its 63rd edition, maintains all its valuable features and much new material. The section on "Welding and Cutting" has been rewritten and expanded to cover Argon Arc Welding, Gas Shielded Arc Cutting, Self-Adjusting Arc Welding, Spark Machining, Oxygen Cutting and Hardfacing. Additional matter has also been introduced into the sections on "Water Engineering" (details of Rainfall and Catchments, Water Treatment and Plant, Reservoirs, Dams, Water Schemes including Pumped Storage); "Iron and Steel" (revised text on Corrosion and Protective Coatings); "Non-Ferrous Metals and Alloys" (revised with additional text and tables); "Foundry Practice" (revision of Diecasting); "Grinding, Abrasives, etc." (details of Blasting Processes, New Abrasive Materials); "Machine Tools" (new tables of machine details, and text includes Cartridge Operated Hammers and Ceramic Tool Tips); "Wire Ropes" (new text and tables); "Harbours and Docks" (revised text on Tides and Movement of Water, also details of Uniform System of Buoyage); "Railway Engineering"—Permanent Way (details of Rail Fastening Devices); "Aerodynamics" and "Aircraft Propulsion" (these two chapters contain revised text dealing with Measurement of Air Speed, Wind Tunnels, Supersonic Flight, Fuels including High Energy Fuels, Compounded Power Units, Helicopters, Parachutes); "Electronic Engineering" (additions to text dealing with Oscilloscopes, Valves and Transformers, including new illustrations); "Atomic Power" (additional text and illustrations); "Heating, Ventilation and Air Conditioning" (revised text and new illustrations of charts for Pipe Sizes, and Flow of Air in Ducts); "Concrete and Reinforced Concrete" (revised in accordance with new specifications).

History of Hydraulics. By Hunter Rouse and Simon Ince. Published by the Iowa Institute of Hydraulic Research, State University of Iowa. 1957. 9¼ in. × 6 in. × ⅞ in. 269 pp. Illus. Price $5.

The material in this book was originally published as a bilingual supplement to *La Houille Blanche* and the English version has now been extensively revised to make the present volume. It certainly makes instructive and enjoyable reading. In following the history of hydraulics as presented in this book, what is surprising is to find that although the Assyrian and Egyptian civilisations depended almost wholly on successful irrigation they do not appear to have established any definite relationship between flow, head and channel dimension. The Greeks, concerned almost exclusively with the theory of ideas, did not trouble themselves with practical hydraulics, and although Archimedes established the laws of buoyancy and is credited with having invented the helical pump which bears his name, he did not advance the science of hydraulics to any notable extent. Nor did the Romans, in spite of their widespread systems of aqueducts for water supply, seem to have had more than an elementary notion of the conditions which govern water flow. Barren years followed, and it was not until the 15th century that the experimental method began to be adopted, and in the hands of such an intellectual giant as Leonardo di Vinci some notable progress was made. From then on, as this book so admirably details, there was no turning back, and although progress was slow at first the 17th and 18th centuries brought the picture of fluid mechanics well into the light; and with the immense impetus given by the invention of the water turbine and more precise measuring devices in the 19th century, both classical and applied hydromechanics were brought together in a fruitful co-partnership. In giving this brief outline we have attempted merely to give the atmosphere of the book, which impresses us as a study in philosophy as much as in hydraulics.

Recommendations for Tests on Impregnated Paper-insulated Metal-sheathed Cables for Voltages of 10kV to 66 kV, excluding gas-pressure and oil-filled cables (I.E.C. Publication No. 55 (Second Edition). International Electrotechnical Commission, 1 rue de Varembé, Geneva. Price 5 Swiss francs.

This second edition replaces the first edition which was issued in 1936.

The tests specified are as follows: *Routine tests*: Conductor resistance test, high-voltage test at works, dielectric power-factor test at ambient temperature, high-voltage test after laying. *Sample tests*: Mechanical test, dielectric security test. *Type approval tests*: Dielectric power-factor test at various temperatures.

Tully Falls Scheme

We are now able to give fuller particulars of the Tully Falls scheme in Queensland, Australia, the official opening of which was announced in an Editorial Note in our November, 1957, issue

FIRST power from the Tully hydro-electric scheme, which has now come into service, is a milestone in the progress of this £16¼ million project and opens a new era in the electrification of North Queensland.

Three stages were initially planned: (i) The Tully Falls section and Kareeya power station with an installed capacity of 72 MW; (ii) The Tully-Cochable section with an additional 15 MW of generating plant, which will utilise the head below Kareeya power station; and (iii) The Tully-Nitchaga section, of 5,400 kW capacity, which will utilise the head of water in the Koombooloomba storage dam together with the fall in the river between the dam and the point above the falls at which the water is diverted to the Tully Falls section. The decision to proceed with stage (i) of the project was made by the Queensland Government in 1950 on the recommendation of the State Electricity Commission. Expenditure to April 30, 1957, totals £11,225,907. The development of Stages (ii) and (iii) as required to meet future demands is now being examined.

The project provides for the interconnection of the whole of the regional supply systems of the State north of the Burdekin River, and will enable the benefits of the Tully Falls project to be extended over combined regional-board areas aggregating 75,100 square miles. The State Electricity Commission's plans provide for the extension of this system to include Charters Towers (which has been recently incorporated in the supply area of the Townsville Regional Electricity Board) and Bowen, and at a later stage, possibly Proserpine and Mackay.

In the meanwhile, great benefits will accrue to both the Cairns and Townsville Regions. This arises from the saving in expenditure on generating costs by the Townsville Board by taking hydro-electricity from Tully Falls instead of generating all of its requirements by thermal power at Townsville. Also, the revenue received by the Cairns Board from the Townsville Board for hydro-electricity supplied to Townsville in excess of its own requirements will permit the average cost of generation in the Cairns Region on a cost-per-unit basis to be substantially reduced.

The Tully Falls section takes advantage of the fall of approximately 1,500 ft. in the river over a distance of some two miles between the diversion weir site, which is at the beginning of a horseshoe bend about one-quarter of a mile above Tully Falls, and the Tully Falls power-house site—Kareeya—in the gorge below. The Tully River rises in the Cardwell Range at an elevation of some 3,000 ft., and the whole of the catchment has a very high rainfall, ranging from an average of 70 in. per annum at Tully Falls to, perhaps, 150 in. in the Cardwell Range. The mean average annual value over the catchment is probably between 90 and 100 in. The area of the catchment above Tully Falls is some 100 sq. miles, and the average flow of the river at the Falls is 500 cusecs. This flow, however, has been very variable. The storage dam at Koombooloomba serves to regulate the river and to ensure that an average flow of not less than 268 cusecs will be always available at the diversion point for the hydro-electric plant. Provision has been made to ensure that flow over the falls will be maintained.

At the head of the falls the river is about 2,160 ft. above sea level. The first section of the falls is about 700 ft., but the river continues to fall rapidly for the first two miles, and flows seaward through a gorge about 2,000 ft. deep.

The main storage dam is seven miles from the falls. The dam has some unorthodox features, and its design has been greatly influenced by site conditions. The bed of the river is granite but unweathered rock does not continue to any height in the sides of the valley. The dam comprises a central concrete spillway section, about 115 ft. above the original stream bed, founded on rock, with earth and rockfill flanks, supported by longitudinal concrete retaining walls, roughly parallel to the river, just clear of the banks. The reservoir has a total capacity of some 152,000 acre ft., of which some 146,000 acre ft. will be available above the outlets. These consist of two 7 ft. diameter pipes controlled by 6 ft. diameter regulating valves. The area of the reservoir at normal full supply level will be about 3,750 acres. In addition to the main dam, two supplementary dams of rolled earth are required to close low saddles on the rim of the catchment.

Balancing pondage is provided by means of a concrete weir about half a mile above the Tully Falls, which also diverts the water into an intake structure. From the intake the water is first taken through the ridge separating the upper reaches of the river and the lower gorge in a 9 ft. diameter steel-lined tunnel a little over 2,200 ft. long, feeding a steeply inclined 6 ft. 3 in. diameter penstock tunnel. Between the two sections is a valve which closes automatically in the event of a burst in the penstock, and adjacent to this is an open-topped surge tank, 18 ft. in diameter. The inclined pressure tunnel is nearly 3,300 ft. long and has a steel lining with a maximum thickness of $\frac{7}{8}$ in. At the lower end it branches into eight distribution pipes to feed the individual turbines in the underground power station.

These turbines are of the double-jet double-wheel Pelton type, with the alternators, rated at 18 MW, located between the two wheels. Two units are installed and a further two units are on order. The water from the turbines is discharged into an underground tailrace and then out to the river below the

falls. The generated voltage is 11 kV and is fed from the machines through underground cables to indoor-type metalclad compound-filled switchgear, 750 MVA rupturing capacity, located in the main control building, situated outside the access tunnel to the station, from which power is distributed in cable to various step-up and step-down transformers for transmission throughout the area and local supply for power control.

The main equipment for the station is located in a large air-conditioned room in the control building which also houses the carrier and supervisory equipment, the battery equipment and standby diesel generators, together with main workshop facilities for the station.

The transformers and high-voltage switchgear are located in an outdoor-type substation adjacent to the control building. The substation is divided into a 66 kV and a 132 kV section, these being the two main transmission-line voltages. Duplicate-busbar construction has been adopted, using aluminium tubes for busbars, supported in fabricated steel structures.

Two 11 kV/132 kV 20 MVA transformers and two 11 kV/66 kV 10 MVA transformers have been installed and a further two 25 MVA 11 kV/132 kV transformers are on order. These transformers are fixed-tap units with OFW type cooling, this method being adopted because of space limitations. Conventional-type airbreak isolators are installed, and small-oil-volume circuit breakers have been adopted throughout.

Carrier-current communication equipment has been provided for the major transmission line, and provision has been made for full supervisory and telemetering at a later date.

Power is transmitted to Innisfail and Cairns over a double-circuit 132 kV transmission line using steel towers and steel-cored aluminium conductors, the highest voltage at present in use in Queensland. This is the first steel-tower project in Queensland and the first time aluminium has been used for a main transmission line in the State. The line from Tully Falls to Cairns is 80 miles long.

The major step-down substations at Innisfail and Cairns supply the main distribution 22 kV network through metalclad compound-filled switchgear after being converted through two 20 MVA O.L.T.C. transformers at Cairns and two 10 MVA O.L.T.C. transformers at Innisfail. Substation structures at these two sites are of reinforced-concrete construction, and aluminium-tube busbars have again been used extensively.

Three 66 kV transmission lines using steel-cored aluminium conductor and erected on single-circuit steel poles, radiate from the Tully Falls station and supply the Atherton Tableland where large step-down substations have been established at Mt. Garnet and Atherton.

Also radiating from the Tully Falls station is the Tully Falls–Townsville interconnection, a double-circuit 132 kV line of identical construction to the other 132 kV line built in the area. This line terminates at Townsville, 160 miles to the south, where a central interconnection substation is being built at Garbutt. The connection between the 132 kV and 66 kV system of the Townsville Board is made through two 20 MVA O.L.T.C. 132 kV/66 kV/11 kV three-winding transformers.

Arrangements have also been made to tap this 132 kV line at Ingham, approximately 60 miles north of Townsville, where a second 132 kV/66 kV interconnection substation with one 15 MVA O.L.T.C. 132 kV/66 kV transformer is to be installed. This substation provides a secondary tie between the Cairns 132 kV network and the Townsville Regional Board's 66 kV system.

Load conditions in the initial stages and the length of the interconnection are such that it has been found necessary to install shunt reactors at Tully in order to operate the line within reasonable voltage ranges. Provision has also been made for the installation of synchronous condensers at a later date.

A Revolutionary Pump Design

A DEVELOPMENT of quite unusual interest in the field of pump design is revealed in the Goodyear pump, which has been placed on the market by Goodyear Pumps Limited, a subsidiary of Holman Bros. Ltd., Camborne, England. The pump is the invention of a Cornishman, Mr. James W. Goodyear, and is all British from start to finish.

The model depicted in Fig. 1 shows the principle of operation. The design reverts to the age-old principle of the screw of Archimedes, but with the vital addition of a rotating dividing plate which prevents backflow and renders the pump positive and continuously self-priming. In fact, the flow is pulseless, and the pump can work either on snore or under pressure.

This method of construction lends itself particularly well to operation at high speed. The ratings of the standard range of Goodyear pumps are based on operation at 1,500 or 3,000 r.p.m., and we are informed that there would be no difficulty whatever in making a pump to run at 6,000 r.p.m. These high speeds mean high pumping capacity, and, indeed, a Goodyear pump seems ridiculously small by comparison with a multi-stage centrifugal pump of equivalent capacity. For example, the Size 7 pump, which is only a single-stage unit, is rated to deliver 30 g.p.m. against a head of 200 ft. when running at 3,000 r.p.m., and will, in fact, lift practically this quantity against a head of 300 ft., but it is only $9\frac{1}{4}$ in. long, $8\frac{1}{2}$ in. high and 4 in. wide, and weighs only 20 lb. in Meehanite iron and 11 lb. in aluminium alloy.

A further claim made for the Goodyear pump is its high efficiency. As will be seen from the curves given in Fig. 2, at the higher heads its efficiency is about 60%. The improvement in efficiency as compared with that obtainable from certain other classes of pump in this capacity range is of double benefit to the user, for the motor or engine can be smaller and cheaper, and the cost of power or fuel is reduced.

In the construction of the pump full advantage has

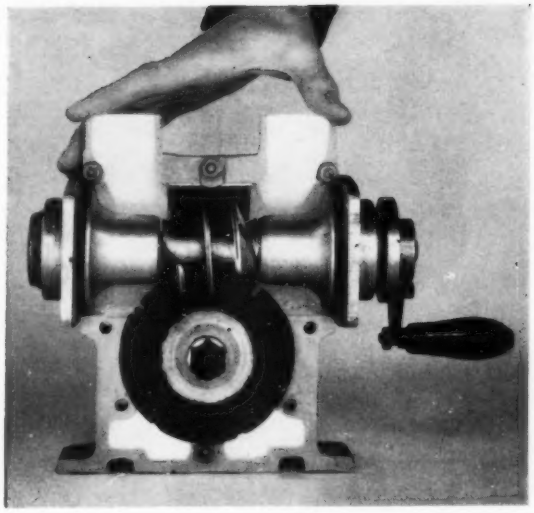


Fig. 1. Model of the Goodyear pump

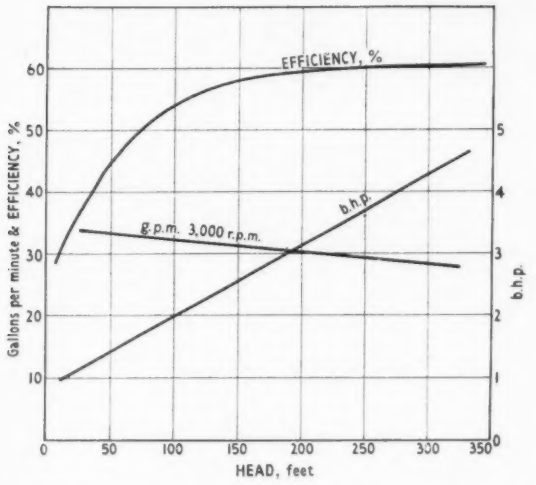


Fig. 2. Curves of efficiency, power consumption and delivery for a size 7–8 Goodyear pump

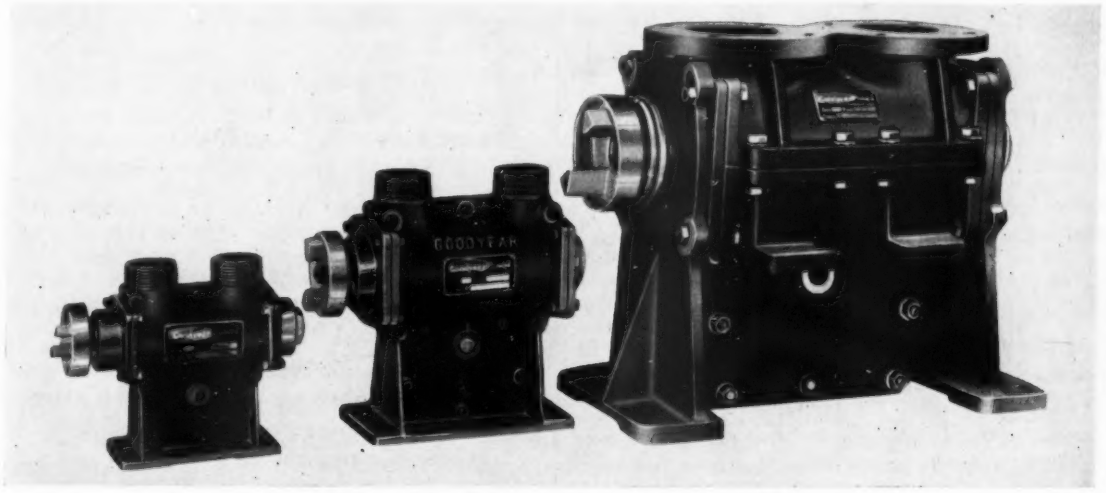


Fig. 3. The three Goodyear pumps in the present range

been taken of modern synthetic-rubber bonding techniques to make all rubbing surfaces in contact with the liquid metal-to-rubber. They are thus self-sealing, self-lubricating, resistant to abrasion, and of low friction. By suitably choosing the coating material pumps can be constructed to handle practically any consistency of fluid, from volatile liquids to molasses, liquids containing solids, and most noxious liquids.

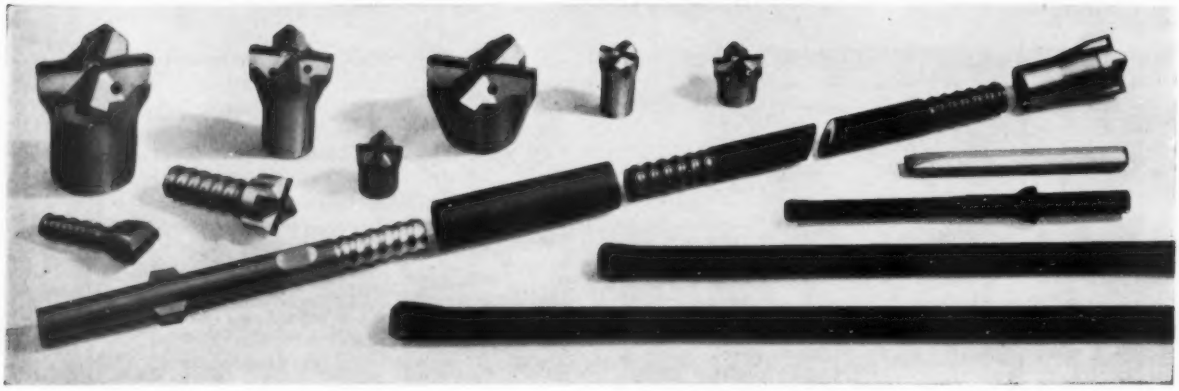
The shaft is of liberal diameter to prevent whipping at high speed, and is mounted on taper roller bearings protected by lip seals. Mechanical seals are fitted in the glands through which the shaft passes through the pumping chamber, and these glands are vented to atmosphere to prevent any leakage reaching the bearings.

A relief valve, discharging back to the inlet branch, is fitted to pumps feeding a delivery line provided with a shut-off valve.

In Fig 3 will be seen the three sizes of pump forming the commencement of the range, and which cover capacities ranging from 5½ g.p.m. at 50 ft. head to 155 g.p.m. at 200 ft. head. It is stated, however, that there is no scale effect with this design of pump, and that once the necessary manufacturing facilities have been developed there is no upper limit to the size of pump that can be built.

Construction Aid During Winter

Polyethylene film is now being used in the United States to enable constructional work to be carried out to an uninterrupted schedule in adverse weather conditions. The accompanying illustration shows the film applied to a three-storey office building; the film was



SANDVIK COROMANT—

A Complete Range of Drill Steel Equipment

You know as well as we do the advantages of buying all your drilling equipment from one supplier. These advantages become still more evident if you buy from the Sandvik Range. The Sandvik Steel Works are the world's largest manufacturers of tungsten carbide for rock drilling. Their production covers integral steels, detachable bits, extension steels and stone working tools—all made of high-quality Swedish alloy steel, all fitted with the well-known Coromant tungsten carbide inserts.

Integral steels with 50% longer life

Sandvik Coromant integral steels have up to 50% longer rod life than ordinary steels, thanks to anti-corrosion SR-treatment, which protects them during transport, storage and actual drilling. In addition, air-tight plastic caps give bit and shank extra protection during transport and storage. They are available in these standard sizes:—

$\frac{3}{4}$″ hollow hexagon	1′4″-13′1″
$\frac{7}{8}$″ hollow hexagon	1′4″-21′0″
1″ hollow hexagon	2′6″-21′0″
Flexible drill steels	2′7″-31′6″

Precision-made rock bits

The threads of Sandvik Coromant (cross and X-design) bits are precision milled. The bits are so accurately manufactured that not only smoother drilling but *longer life* are ensured. Standard bit diameter sizes range from $1\frac{1}{2}$″ to $4\frac{1}{2}$″. The 773 bits (bottoming type) are available with GD400 and GD600 thread, or with $1\frac{1}{4}$″, $1\frac{1}{2}$″ and 2″ rope thread. The 776 bits, for standard shoulder-type drill rods, are available with threads ranging from $\frac{7}{8}$″ to $1\frac{11}{16}$″.

Efficient extension steels

The rope-threaded joints of Sandvik Coromant extension steels are solid and make joining and unscrewing extremely easy. Sizes available: $\frac{7}{8}$″ and 1″ hexagon steels, $1\frac{1}{4}$″ and 2″ round steels. A special feature of the $1\frac{1}{4}$″ equipment is the $\frac{1}{2}$″ flushing hole, about twice as large as most. This gives better cleaning of the bore hole and a higher rate of advance, reduces wear and risk of steels sticking. The 'cold rolling' technique makes this wider flushing hole possible *without any loss of strength*.

Wide variety of Stone Working Tools

A single plug hole steel made by Sandvik is capable of drilling up to 1000 holes, each about 3.9″. Sandvik Chisel Steels are made with rubber sleeves to reduce vibration and protect the worker. Sizes available: Plug Hole Drill Steels with bit diameters ranging from approx. $\frac{21}{32}$″ to $\frac{7}{8}$″. Chisel steels with bit diameters from approx. $\frac{5}{16}$″ to $\frac{25}{32}$″.

The World's foremost drilling unit

Sandvik Coromant extension and drill steels have been developed in close co-operation with Atlas Copco, manufacturers of rock drills and other compressed air equipment. The combination of Sandvik steels and Atlas Copco rock drills is the world's most widely used drilling unit—responsible for the drilling of more than one thousand million feet each year!

The Sandvik Coromant accessories featured here are sold and serviced throughout the world by the Atlas Copco Group of Companies. We have mentioned only the most important products and sizes: for further details, please contact your local Atlas Copco Company or Agent, or write to Atlas Copco AB, Stockholm 1, Sweden.

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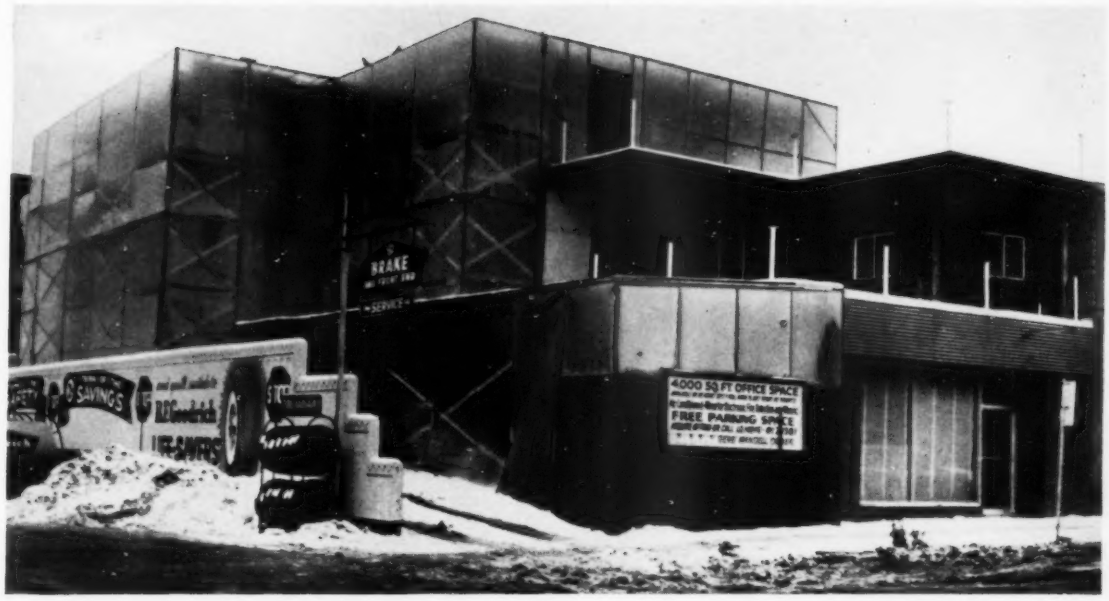


Fig. 1. Three-storey building being built under a polyethylene canopy

erected on a specially constructed scaffolding and kept the internal temperature at about 40°F. (4·4°C.) without artificial heat, even when outside temperatures fell to 10°F. (12·2°C.). Use of the film allowed the builder to pour concrete without the need of chloride or other chemical additives. It is stated to have withstood heavy snow and ice loads and winds with a recorded velocity of up to 42 miles per hour (68 km. per hour). The scaffolding was of wood and had to be stayed down to withstand the wind pressure, but the polyethylene, which was nailed to the scaffolding, did not tear. The scaffolding was carried up high enough to bridge over the roof, and the work inside this protection was enabled to proceed in comfort for the workmen who were, indeed, able to do without gloves in zero weather.

Despite the load of snow carried by the roof section throughout much of the winter, the tough polyethylene film withstood the burden and is in good enough condition to be used again on further contracts. It was supplied by the Union Carbide International Company, New York.

Pectacrete All-Weather Cement

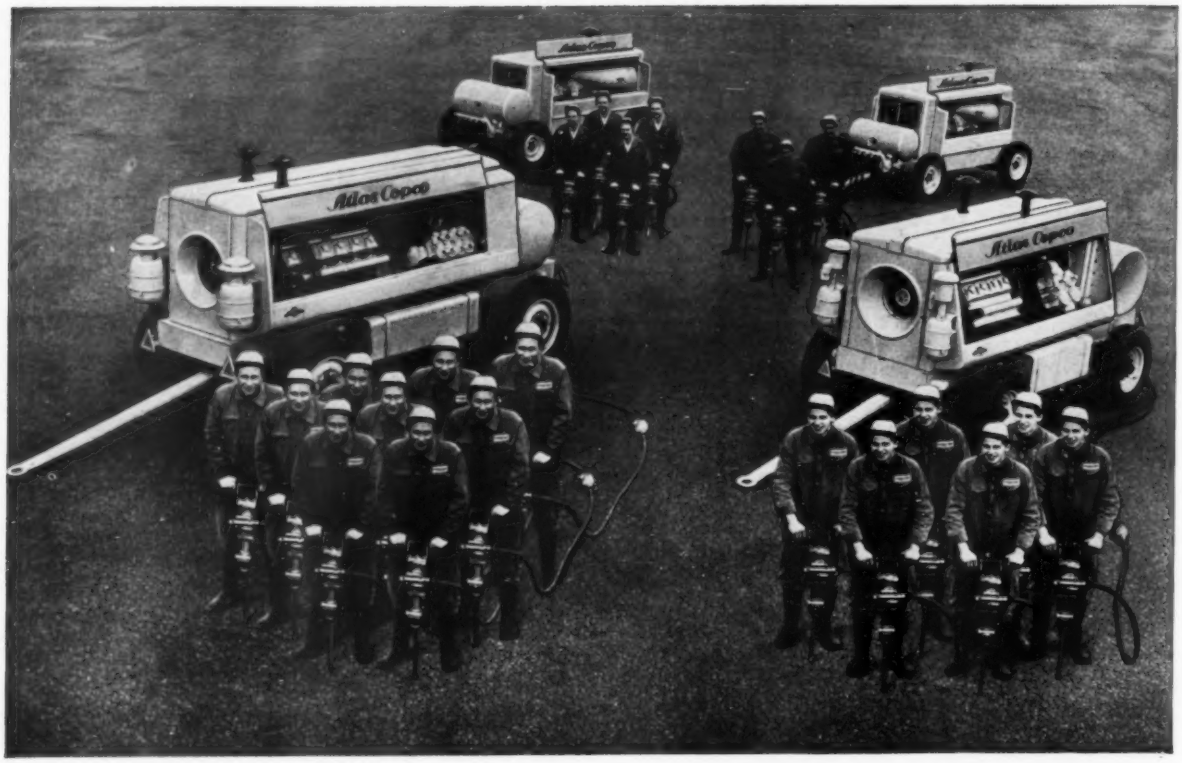
Pectacrete, a new type of cement developed by Pectacrete Cement Limited, and produced and marketed by The Rugby Portland Cement Co. Ltd., is a practical quality of hydrophobic cement which, it is claimed, offers complete protection against deterioration under even the most humid conditions. Wastage of ordinary Portland cement by exposure to moisture during storage and transit can reach serious proportions. Very often expensive protective measures have to be taken against moisture, particularly at wet construction sites; and in the tropics, where high relative humidities are normal, it is almost impossible to prevent cement from deteriorating within a few months.

The principle of Pectacrete is relatively simple; it is produced in normal cement plants but during the final grinding of the clinker a minute quantity of chemical additive is sprayed into the mill. This additive forms a protective coating around each particle of cement and inhibits hydration until broken by mechanical abrasion in the presence of water. Break-up of the coating is stated to be instantaneous; there is no delay in the period of mixing and no special knowledge is needed by the operator. After mixing, hydration of the cement proceeds normally. Pectacrete is claimed to exceed by a considerable margin all the requirements for strength, setting times, soundness and workability, of B.S.12:1947 for ordinary Portland cement. Workability and cohesiveness are increased, however, and mixes can be designed with much lower water:cement ratios. The resulting concrete is also impervious to the penetration of water. This property is of particular value in reinforced concrete work as it avoids corrosive attack on the reinforcement or spalling as a result of frost action. Table I gives comparative absorption values for prisms made with ordinary Portland and Pectacrete cements.

TABLE I

Sample (1 : 3 cement mortar)	Weight of water absorbed	
	Partial immersion for 24 hrs.	Total immersion for 24 hrs.
Normal Portland cement	21 gm.	23 gm.
Fresh Pectacrete cement	5 gm.	8 gm.
Pectacrete cement after 9 months' exposure to the atmosphere	2 gm.	10 gm.

Proof of the hydrophobic properties of Pectacrete has been demonstrated by standing two heaps of



Atlas Copco 500Dd, air-cooled, two-stage compressor, with Deutz, 12-cylinder air-cooled diesel engine. Sufficient to operate 9 rock-drills.

Atlas Copco 225Dd, air-cooled, two-stage compressor, with Deutz 6-cylinder air-cooled diesel engine. Sufficient to operate 4 rock-drills.

Atlas Copco 160Dd, air-cooled, two-stage compressor, with Deutz 4-cylinder air-cooled diesel engine. Sufficient to operate 3 rock-drills.

Atlas Copco 325Dd, air-cooled, two-stage compressor, with Deutz 8-cylinder air-cooled diesel engine. Sufficient to operate 6 rock-drills.

4 new 100% air-cooled portables

Capacities up to 600 cubic feet

Featured above are four of the new Atlas Copco range of completely air-cooled portable compressors—both compressor and diesel engine being 100% air-cooled. This new range is the most comprehensive of its kind in the world with capacities from 36 cu.ft./min. to 600 cu.ft./min., the latter being the highest capacity unit with complete air-cooling obtainable from any manufacturer.

World-wide sales and service

Atlas Copco puts compressed air to work for the world. It is the largest group of companies specialising solely in the development and manufacture of compressed air equipment. It embraces Atlas Copco companies or agents manufacturing or selling and servicing Atlas Copco equipment in ninety countries throughout the world. For further details of the equipment featured here, contact your local Atlas Copco company or agent, or write to Atlas Copco AB, Stockholm 1, Sweden.

Standard Features

Complete air-cooling—both compressor and engine air-cooled giving an equal, simple and economic design. Cuts out cooling system troubles, freezing damage, thermostats, radiator blind, anti-freeze solution, and boiling radiators in warm climates.

Fuelmiser—revolutionary stageless automatic speed control and automatic unloading device. Saves 15%-20% of fuel.

Lubromatic clutch governed by the oil pressure—safe and easy operation. If compressor runs out of oil the clutch disengages automatically.

Automatic Drain Cock on air receiver—one thing less for the operator to take care of.

High efficiency oil-bath air intake filters.

Force-feed lubrication.

Automatic type steering, low centre of gravity and wide track—makes transportation easy.

Electric starting mechanism—gives quick, easy start.

P7

Atlas Copco

Manufacturers of Stationary and Portable Compressors, Rock-Drilling Equipment, Loaders, Pneumatic Tools and Paint-Spraying Equipment

cement, one of Pectacrete and one of ordinary Portland cement, on porous plates under exactly similar conditions and measuring the quantity of water picked up by each in a given period. In a typical test, after 24 hours exposure, Pectacrete was found to have increased its weight by only about 5·25% whereas the ordinary cement showed an increase of around 63·75%.

Because of its smooth flow it is claimed to have marked advantages when used in pumped concrete, as the self-lubricating characteristics introduce little frictional resistance. Excellent finishes are stated to be possible and "bleeding" is almost non-existent. This characteristic is of importance on concrete road works, external rendering, grouting (particularly of prestressing cables), and "Guniting."

The price is slightly higher than that prevailing for ordinary Portland cement.

"Saturnus" Turbulence Meter

THE "Saturnus" is the name given to a turbulence meter which has been developed by the Hydraulics Laboratory, Delft, for gaining information on the forces which act on the bed material downstream of outlet works and cause bottom erosion. The immediate objective was to find the most economical means of preventing scour at a large discharge sluice, containing 16 openings each 60 m. wide, in one of the closing dams to be erected as part of the Delta project in the Netherlands.

The first need was to carry out a large number of turbulence measurements in practical conditions and for this purpose one of the discharge sluices of the Zuiderzee dyke was chosen. These measurements had the objective of correlating the measured velocity fluctuations with the charted bottom alterations and of comparing the results in nature with those obtained in a scale model.

With this programme in mind, the possibility of converting turbulent velocity fluctuations into measurable electrical quantities was considered. This idea was derived from a conception of Sir Claude C. Inglis, F.R.S., who suggested the deviation from zero of a ring, held in equilibrium by springs, as a measure of the velocity component in the plane of a ring. Using this principle the Hydraulics Laboratory, Delft, have devised a robust instrument, having a high natural frequency and well able to withstand mechanical shocks. This instrument is illustrated in Fig. 1. It consists of two semi-spherical ends a_1 a_2, connected by two cylindrical parts b, c and four connection pieces d and four bolts e, all made of mild steel. f is a stainless-steel ring with an axis g, supported by two phosphor-bronze membranes h_1 h_2. One of these supports has been made adjustable in order to give the axis its correct position. A laminated core j is clamped on to the axis. Eight brass strips, fixed between the hemispherical ends, serve as a protection against damage. The stator k is fixed to the inner wall of the cylindrical portion c, this housing being rendered watertight by the phosphor-bronze bellows l.

Deflections of the axis g are measured by means of a 3-phase variable-reluctance system which was devised by Mr. S. L. Boersma, an electronics consulting engineer. Fig. 4 is a diagram of the winding of the stator which is supplied by a 1,000 herz 3-phase vacuum-tube oscillator. In the zero position (no current) the core is concentrically positioned in the stator, the air gap around it being of equal width at all points. The three self inductances r, s and t energised by a 3-phase voltage are then equal and there will be no output voltage at the common point a. When the core is deflected, however, an output voltage will develop at a having an amplitude propor-

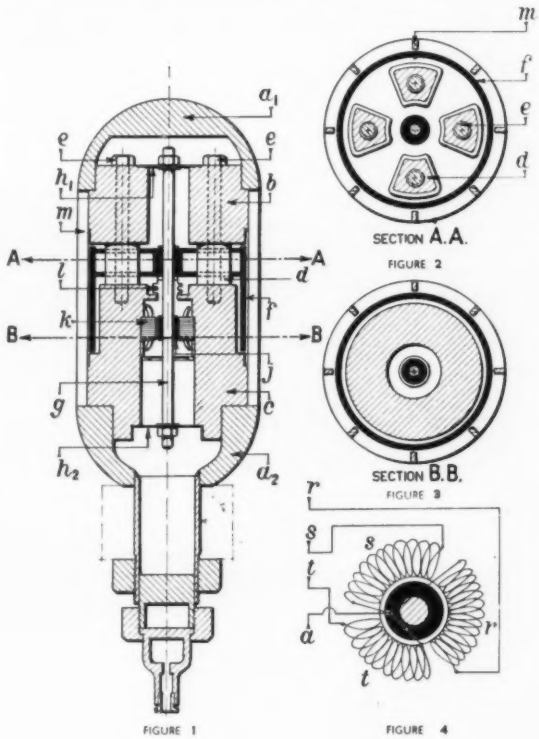


FIGURE 1

FIGURE 2

FIGURE 3

FIGURE 4

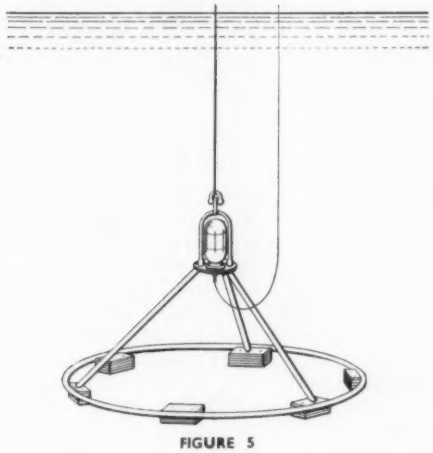


FIGURE 5

Intake Gates

Illustrated is a completely assembled Intake Gate being lowered into position. This is one of twelve built by Canadian Vickers for the Pumped Storage Scheme part of the Sir Adam Beck No. 2 Development of the Hydro Electric Power Commission of Ontario, at Queenstown.

Shop welded in sections and riveted together in the field, these Gates are designed for a clear opening of 16′-8¾″ wide and 34′-9″ high and subjected to a maximum head on the sill of 77′-6″.

Canadian Vickers designs and builds all types of Water-Way and Water-Power equipment. If it is Vickers-built . . . it's right.

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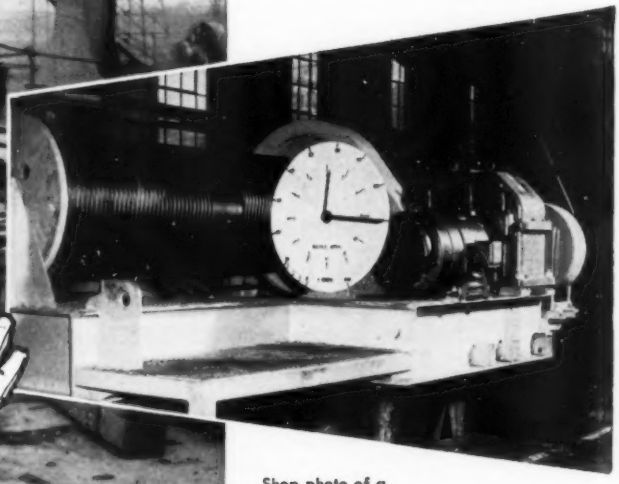

Shop photo of a Vickers-built Hoist.

tional to the deflection and a phase equal to the azimuth of the deflection. This voltage is fed over a fourth conductor in the connecting cable to an a.c. amplifier in the instrument case. Seeing that the deflecting force and the resulting voltage are proportional to the square of the water velocity inducing the deflection, the amplifier is given a square-root amplitude characteristic and feeds simultaneously into three detectors. The detector signals can either be fed into pen recorders or into a cathode-ray oscilloscope. The instrument can conveniently be mounted on a tripod (Fig. 5) which is placed on the bottom of a water course while the recording apparatus is placed on the river bank, the two being electrically connected. A full description of the "Saturnus" meter is given, in English, in publication No. 10, Series 4, issued by Waterloopkundig Laboratorium, Raam 61, Delft, The Netherlands.

Abstracts from the World Technical Press

New Type of Cofferdam Cell

The introduction to this article sounds rather like a declaration of war on concrete insofar as it is used in hydraulic structures. Developed by the author initially for marine works, it is claimed that his new technique could equally well be applied to some of the structures occurring in hydro-electric schemes such as cofferdams, etc. Compared with concrete, the following main advantages are claimed; low cost, substantial reduction in volume, and easier construction work because of lightweight elements whose stability is secure as soon as they are fitted into position. These elements consist essentially of a thin cylindrical shell of rolled or enamelled metal with walls lined on both sides with a membrane of vinyl chloride or some polyester reinforced by spun-glass fabric. To close, for example, a 15 m. gap, the cofferdam could consist of three elements each 5 m. in diameter, set up in contact with each other, either vertically or at a slight slant, and filled with sand or any other convenient material available on site to ensure their stability. While a gabion-type cofferdam acts exactly like an earthfill dam or dyke, all stresses being transmitted to the filling material, in a multi-cell cofferdam of the new type it is the shell encased between the two membranes which absorbs the stresses, particularly the shearing stress. In fact, in contrast to the shifting which occurs in gabion-type cofferdams, a cofferdam of the new type hardly buckles or warps when put under pressure. This applies more especially to structures erected in flowing water in which, to return to the example mentioned above, the pressure of the flow acts upon a width of 5 m., i.e., the diameter of an element, instead of 15 m., as in the case of a gabion-type cofferdam. It is a most important point in this type of cofferdam to ensure the preservation of the shells of the cylindrical elements. Fortunately, sheets of enamelled or rolled metal laid between two layers of vinyl chloride or polyester reinforced by spun-glass fabric, combine a very high degree of mechanical resistance with an absolute resistance to corrosion, even against sea-water. The small size of the elements is, of course, a great asset, as they can be easily handled and erected. The author examines the various conditions under which his new type of cofferdam cell can be used, underlines the resistance of their shell to distortion, and explains how they can be applied to the building of U-shaped cofferdams in river or tidal currents. Tests carried out on scale models as well as on actual structures under operating conditions, are also described. After listing various instances of possible application to protective works, such as quay walls, piles and dams, the author outlines a general method of design calculation, and also refers to the possibility of their use in the closing of coastal river estuaries. The paper concludes with some indications of costs. (J. Velut, Ingénieur P. & Ch., *Travaux*, Vol. 41, No. 274, August 1957, p. 425, 11 pp., 13 ff.)

Moiry Dam Completed

This new dam, included in the Gougra River development, was recently completed. The structure is of the arched type, reaches a height of 145 m., and has a crest length of 610 m. It involved the placing of 810,000 cu. m. of concrete and creates a reservoir having a capacity of 72 million cu. m., corresponding to a storage reserve of 256 million kWh. Upon completion of the whole development, the Motec power houses, the Vissoie plant and the existing plant at Chippis-Navisence the scheme, the scheme will have a capacity of 164 MW and an average yearly production of 555 million kWh, 336 millions of which will be generated during the winter months. (*Bulletin de l'Association Suisse des Electriciens*, Vol. 48, No. 25, December 7, 1957, p. 1,138.)

Stream Functions in Three-Dimensional Flows

Stream functions, though efficiently defined in various instances, have usually been restricted, since introduced by Lagrange in 1781, to instances of two-dimensional incompressible fluid flow. Sixty-one years later Stokes invented the stream function for axisymmetric flows of an incompressible fluid in precisely the same manner as Lagrange. Two questions now naturally arise: (a) For three-dimensional flows, do stream functions exist in terms of which the velocity components can be expressed? And (b) if so, does a general relationship exist between the discharge and these stream functions, which includes Lagrange's and Stokes' stream function as special cases? In this paper the author shows that stream functions exist for general three-dimensional flows of a non-diffusive fluid except unsteady flows of a compressible fluid. A simple definition of the velocity in terms of the stream functions has been given whenever the later exist: this definition includes all those known for flows as special cases, and yields a simple relationship between the volume or mass discharge and the values of the stream functions, from which all the well-known ones for special flows can be immediately deduced. For unsteady flows of a compressible fluid three "path func-

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tions" exist in terms of which the density and the products of the density and velocity components can be expressed and this in such a way that the equation of continuity is satisfied. The mass contained in three pairs of surfaces which are time-traces of the material surfaces (or hypersurfaces) corresponding to specific values of the "path functions" is shown to be the product of the three differences of these functions. An analogous development for vorticity (instead of velocity) results in a similar relationship between the circulation and the vorticity functions. (Chia-Shun Yih, Iowa Institute of Hydraulic Research, State University of Iowa, *La Houille Blanche*, Vol. XII, No. 3, July–August 1957, p. 439, 6 pp.)

NOTE: The original paper in English also appears in the above-mentioned Journal and follows the French translation.

The Hydraulic Jump

The author first reviews the problems presented by the (non-undulated) hydraulic jump; conjugate depths, length, and head loss, and then gives the classical solution (horizontal channel with a rectangular cross-section), followed by a proposed solution for the general case of prismatic channels of any cross-section or slope; expression for the conjugate depths, first in dimensional and then in dimensionless form; length of the jump and head loss. Finally, the degree of validity of the proposed equations is examined, together with the experimental check required.

This article first appeared in French in *La Houille Blanche*, Vol. 9, No. 6, 1954, pp. 811 to 822, and is now reproduced in English as a 12-page supplement to Vol. XII, No. 3, July–August 1957, of the same journal, but without the diagrams. (J. O. de Mello Flôres, professor at the University of Brazil; translation by Jan C. Van Tienhoven, of the Research Centre, Waterways Experiment Station, Vicksburg, Miss., U.SA.)

Aerial Survey Methods in Canada

This is a small-scale symposium on the application of aerial photography and geophysical techniques to the estimation of the natural resources of large territories such as the Canadian northland. Many fields of engineering are involved in the work and the methods applied in Canada furnish an exceedingly useful contribution to the planning of hydro-electric schemes. Fig. 3 of the article shows the photographic interpretation of conditions around a proposed dam site, a wider circle defining the area in which the sources of construction materials such as bedrock, gravel, impermeable fill, etc., are desired. A smaller circle shows areas where overburden depths have been mapped. (H. S. Scott, *The Engineering Journal*, Canada, Vol. 40, No. 11, November 1957, p. 1,647, 10 pp., 10 ff.)

The Maithon Power Station

This is the last of the Damodar Valley Corporation's three multiple-purpose projects included in the first stage of this great development. The project is on the Barakar River, the biggest tributary of the Damodar, and its drainage area above the Maithon dam is about 2,430 sq. miles. Maithon dam is a composite structure which consists of a rockfilled earth embankment on the original bed of the river, a concrete gravity spillway section across the diversion channel, a long earth dyke, part of which will act as a breaching dyke, and the power plant with all the ancillary installations, including intake structure and tailrace. The underground power plant accommodates three 25 MVA units, and has an installed capacity of 60 MW. A detailed description of the whole plant is given. (K. M. Chinnapa, *Indian Journal of Power and River Valley Development, Maithon* Dam special issue, 1957, p. 29, 11 pp., 5 ff.). NOTE: The general features of the Maithon underground power house are reviewed and discussed in another article of the above issue. (N. L. Mulay, p. 39, 6 pp., 2 ff., 3 plates.)

Saarner Aa Plant Inaugurated

Following the commissioning of its two generating sets in May and the end of July 1956 respectively, the Saarner Aa power station was officially inaugurated on October 10, 1957. The main characteristics of the plant are: discharge 12 cu. m. per sec.; net head 20·25 m.; installed equipment, two 2,400 kW vertical Kaplan turbines, two three-phase alternators operating at 5·2 kV, 3,300 kVA; average output 14 million kWh. The weir-type dam at Zelgwald, upstream of the confluence of the Grosse Schliere with the Saarner Aa, creates a backwater extending 2 km. upstream, with a storage of 400,000 cu. m. which is not used as balancing reserve. A pressure tunnel 1,865 m. in length, excavated in the rock overhanging the river, conveys the water to the power house erected near the Alpnach bridge. Another tunnel, 70 m. long, acts as tailrace. The two 1,650 kVA transformers placed in front of the power house, step up the voltage from 5·2 to 12 kV to feed the network of the Central Kraftwerke concern. (Mo./Sa., *Bulletin de l'Association Suisse des Electriciens*, Vol. 9, No. 11, November 1957, pp. 1938/1939, 2 ff.)

Freibach Project

The medium-sized Austrian scheme described in this article will open to hydro-electric production a region of south-eastern Carinthia which had been heretofore surprisingly neglected, since the conditions it offers are uncommonly favourable. The Freibach mountain stream is a right-bank tributary of the Drau; in its middle course a 196,000 cu. m. earth-fill dam will create a useful storage of 4·4 million cu. m.; fill material and clay for the core are available on the spot. The spillway section of the dam will be designed for an overflow of 200 cu. m. per sec., corresponding to a 1,000 year flood. The pressure supply conduit, designed for a maximum discharge of 5·75 cu. m. per sec., has uncommon features. From the valve chamber of the dam, a short pressure-tunnel section, 166 m. in length, connects with a 1,020 m. pipeline, followed by two further tunnels 832 and 1,167 m. long respectively, separated by a 440 m. pipeline. The tunnel sections are uniformly 2·0 m. in diameter and the pipelines 1·70 m. The latter, laid along the flank of the valley, consist of 5 m. long prestressed-concrete steel-armoured sections 12 cm. in wall thickness, which will be cast on site. Completed pipe sections are subsequently fitted with coils of 5 mm. prestressed steel wire and ultimately covered with a "Torkret" layer about 2 cm. thick. The steel penstock leading

from the surge tank to the turbines varies in wall thickness between 8 mm. at the top and 24 mm. at the bottom end, and, in diameter, between 1,650 and 1,200 mm. It is divided by anchor blocks into five sections, and buried sections are protected from corrosion by asphalt bands. The power house erected at the foot of the hill will be equipped at the outset with a 22,000 h.p. generating set, provision being made for the addition at a later date of a 5,000 kW pumping unit. The turbine will operate from a net head of 317·9 m., and yearly production is assessed at 40 million kWh, 55% during the winter and 45% during the summer. A 100 m. tailrace will return the discharge from the turbines to the Drau River. (F. Jeran, Klagenfurt, *Oesterreichische Zeitung für Electrizitäts wirtschaft*, Vol. 10, No. 7, July 1957, p. 193, 5 pp., 5 ff.)

Recent Developments in Fluid Mechanics

This paper attempts a survey of existing knowledge in four fields of fluid mechanics. Following an introduction, in which the author explains why he speaks of "fluid mechanics" instead of using the older term "hydraulics," the problem of sediment transport is first set forth and discussed, separate paragraphs in this section being devoted to the threshold of movement, sediment load, Lacey's regime theory, and the determinacy of the sediment transport problem. The second and third topics tackled are of special concern to the hydraulic engineer, dealing as they do with two of the most important problems connected with the setting up of dams, spillways and associated structures: Flow under a dam on a permeable foundation, and free-boundary problems. The paper concludes with a short chapter on the swimming of marine organisms. In the first three topics, the survey is supplemented by a description of recent work done by the writer and his students at the New Zealand National School of Engineering, and in the fourth by a description of recent observations made in New Zealand on one example of the general problem. Since each of the topics treated has its own convention relating to symbols, it would have been impossible to use one group of symbols covering the whole paper; symbols are therefore defined as they occur in the text. It will be found that no confusion arises from this practice. (F. M. Henderson, Senior Lecturer in Civil Engineering, Canterbury University College, *New Zealand Engineering*, Vol. 12, August 15, 1957, No. 8, p. 265, 15 pp., 26 ff.)

Determining Stresses in Penstock Anchor Blocks

This is a reprint of the paper read by the author at Buffalo, U.S.A., in June 1957. At the outset, a survey is given of the continuous, interimttent and abnormal stresses, both static and dynamic, occuring in the various types of penstock: welded or overpressured pipelines with or without expansion joints, and self-hooped penstocks. The same problems are then reviewed according as the penstock is empty, full without pressure, and full under pressure, as well as for surface, buried, concreted and tunnel-housed pipelines. There follows a computation of the various stresses, special attention being devoted to pipelines with unanchored elbows. Practical examples of stability calculations are given for the penstock itself as well as for an anchor block, emphasis being laid in both instances on the savings that can be achieved by a correct analysis of the stresses affecting a penstock. The paper ends with specific data on anchor piles and their behaviour, and some considerations on the importance of a close co-ordination in the work of planners, designers and manufacturers of penstocks, not to mention contractors. (Robert Bouchayer and Claude Tascher, *Travaux*, Vol. 41, No. 278, December 1957, p. 625, 17 pp., 54 ff.)

Submerged Flood-Control Orifices

A description is given of the flood-control system introduced by the Kansai Electric Power Company into the design of its Tonoyama dam, a 210 ft. high thin-arch dam set up on the Hikigawa River, 60 air miles from Osaka. The system consists of six submerged bell-mouthed orifice openings that can discharge 88,000 cu. ft. of flood waters under a 74 ft. head. On three occasions since the project was completed, the orifices, equipped with inclined lifting gates, performed admirably. The jets discharged into a stilling basin 300 ft. downstream from the toe of the dam. Two considerations militated in favour of this uncommon flood-control system: an exceedingly high flood discharge at typhoon periods, which occur rather frequently, coupled with a V-shaped gorge at the dam site only 50 ft. wide at the river level and 350 ft. wide at the top of the dam. On the downstream face of the dam, the inclined steel gates of the six orifices, 20 ft. wide and 16·5 ft. high, can pass 83% of the 106,000 cusec. design-flood discharge, while six conventional crest gates 20 ft. wide by 5 ft. high cope with the remainder. Other notable features of this all-Japanese project are the use of a Kaplan turbine under 230 ft. of gross head plus the excellent earthquake resistance of the arch dam. (A. E. Niederhoff, *Engineering News-Record*, Vol. 159, No. 14, October 3, 1957, p. 50, 3 pp., 6 ff.)

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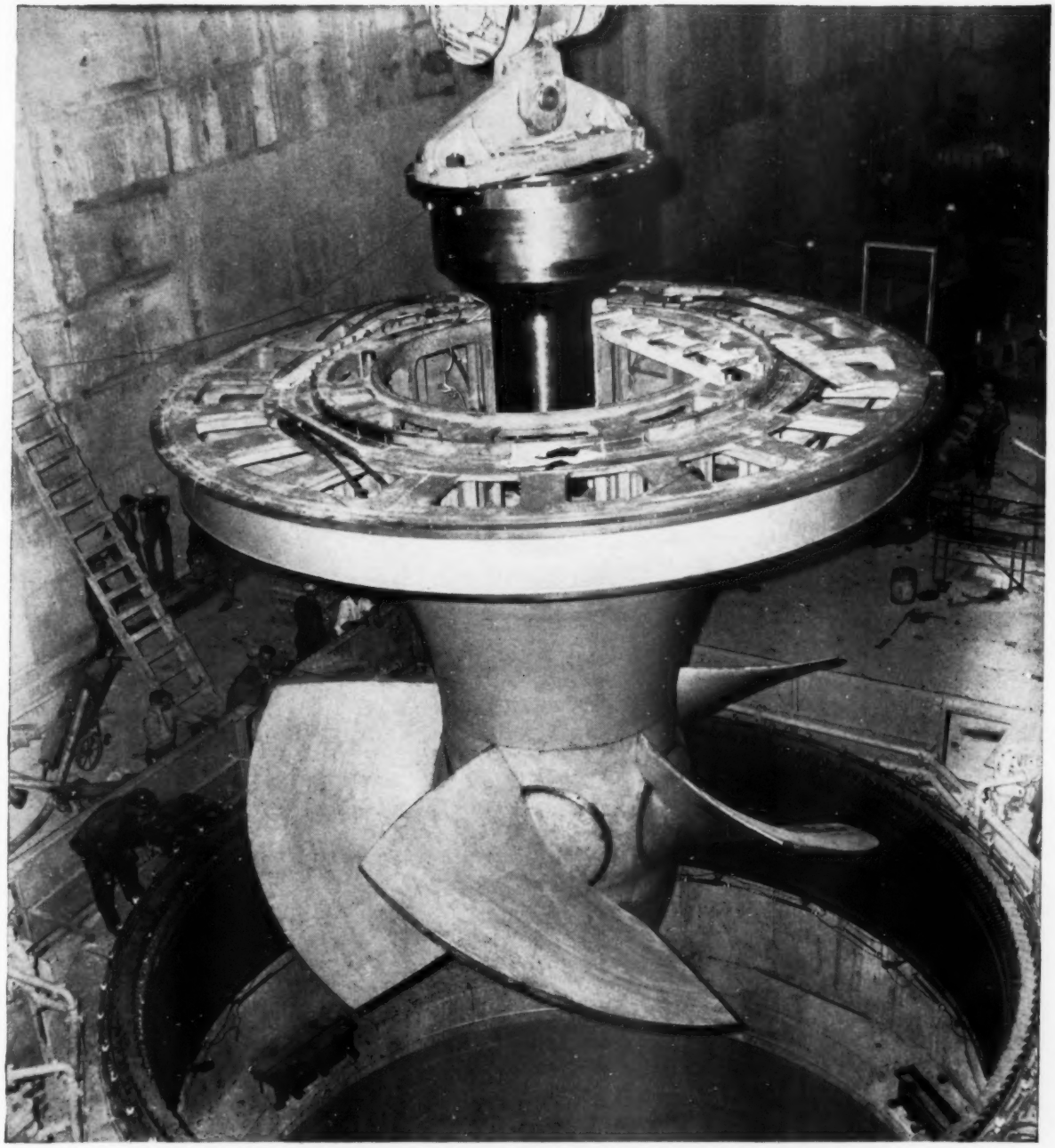

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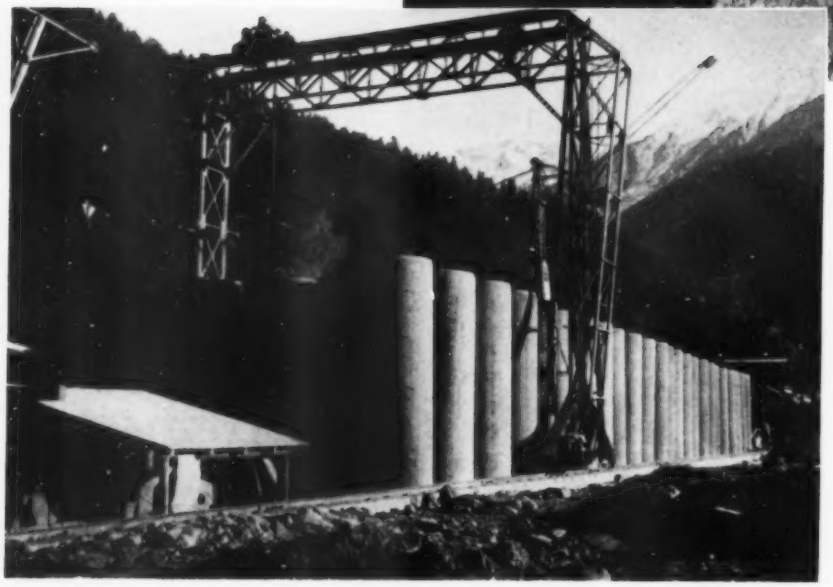

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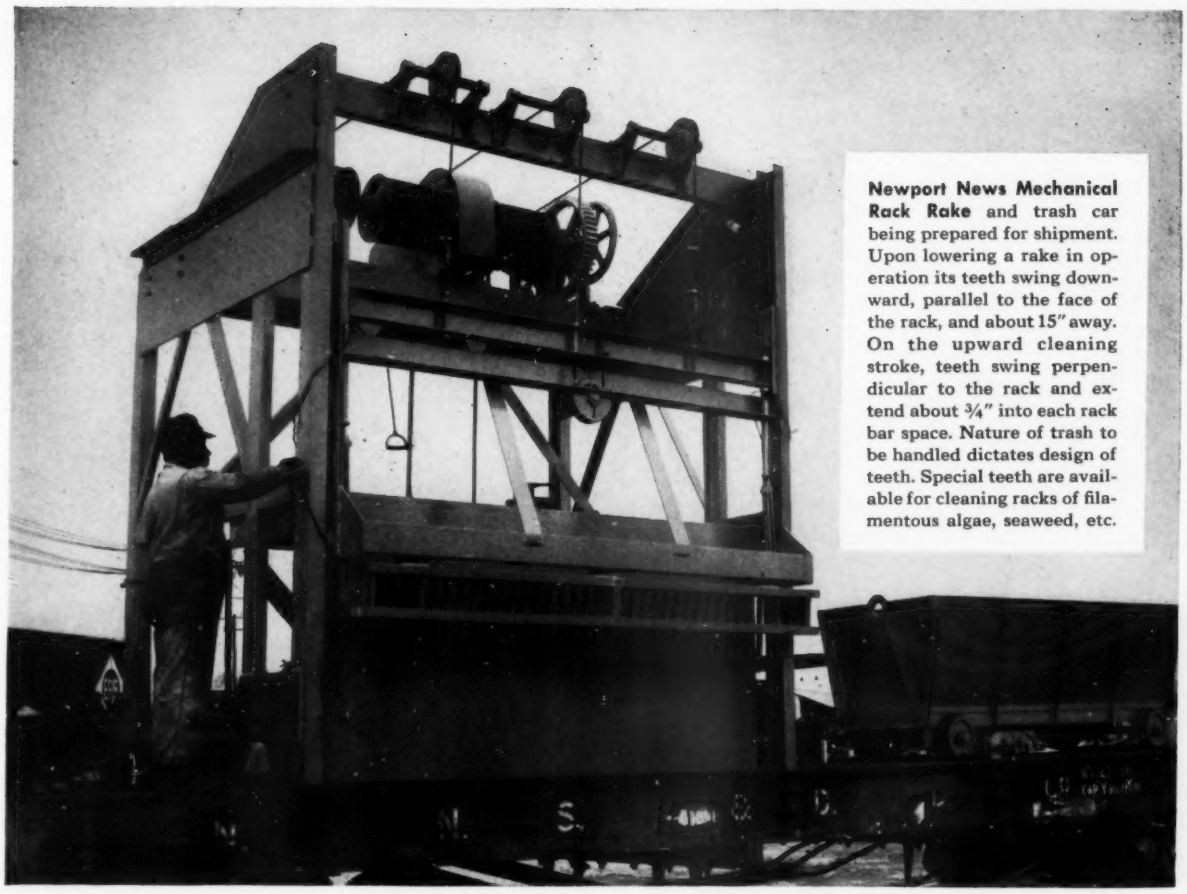

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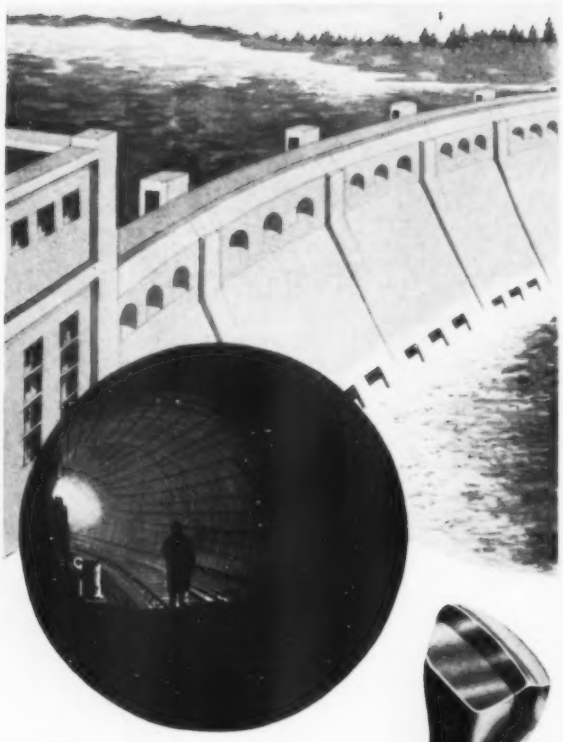

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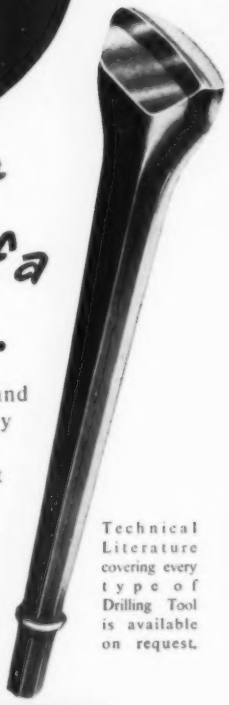

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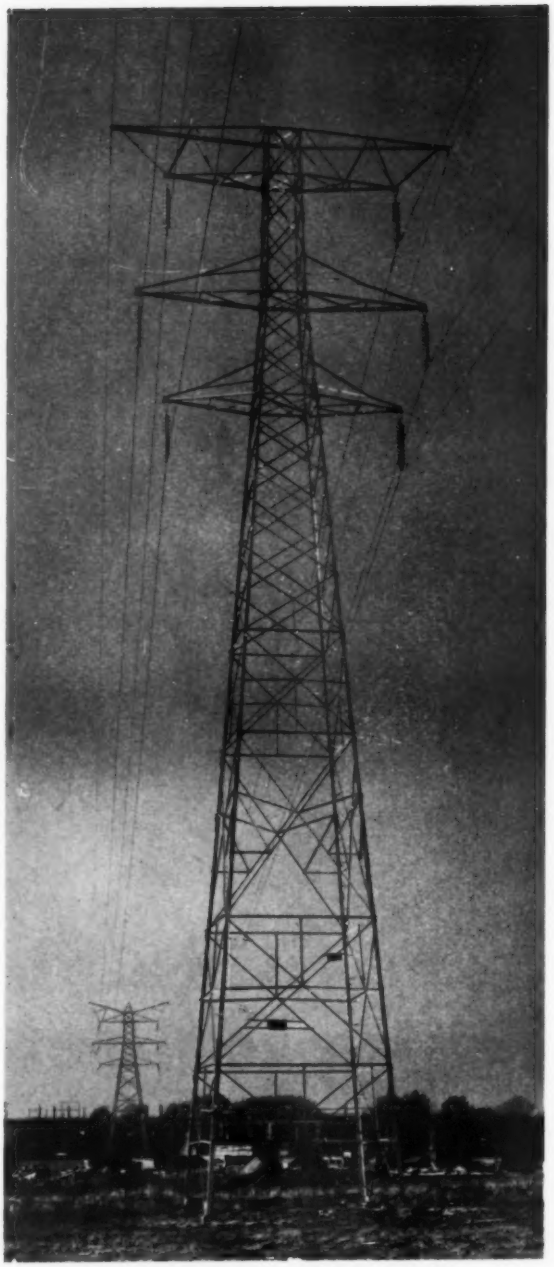

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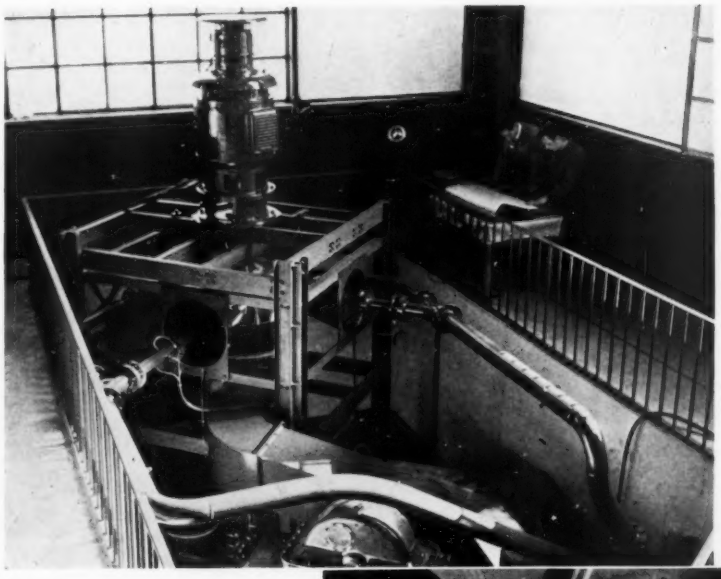

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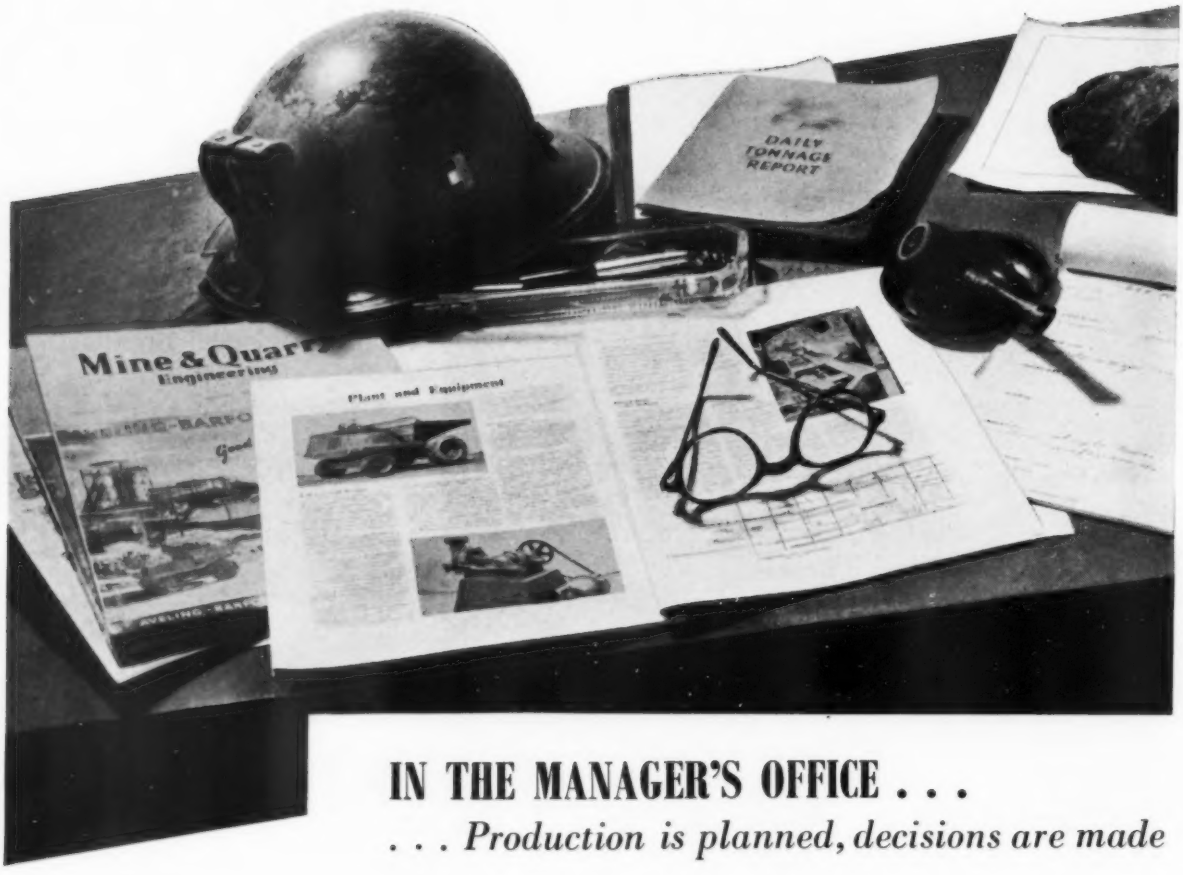

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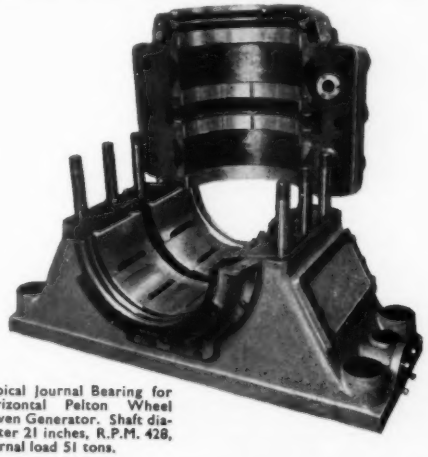

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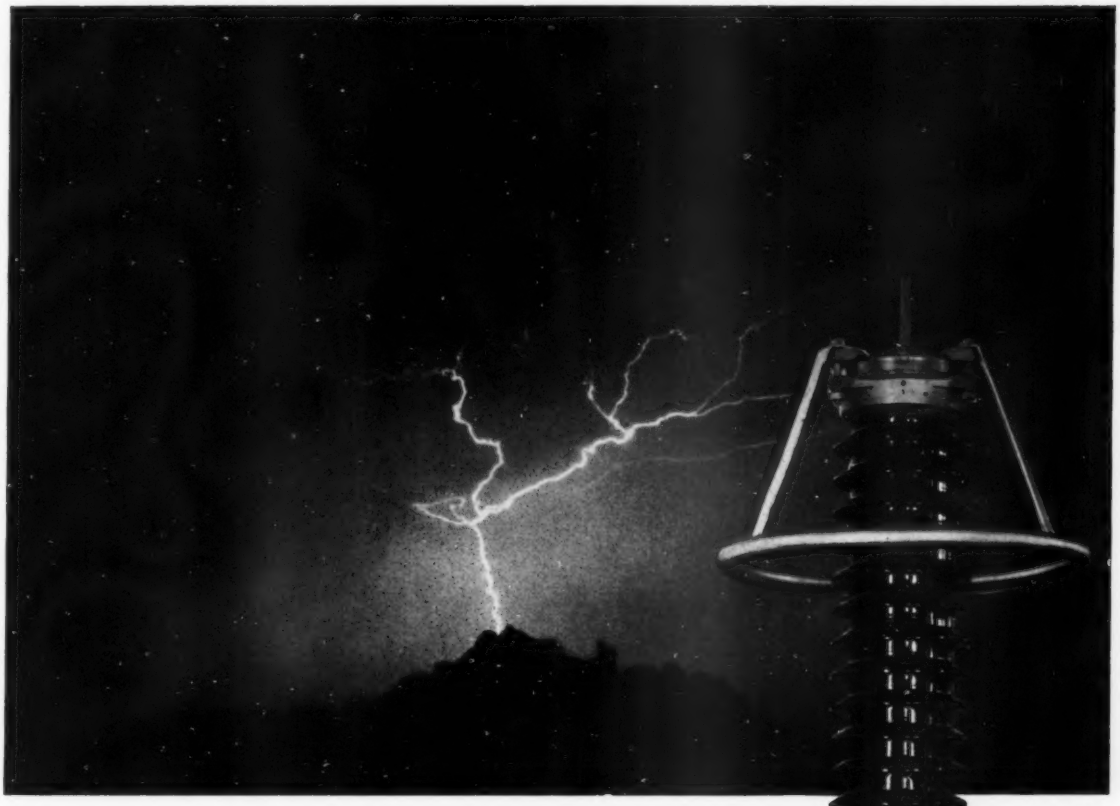

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